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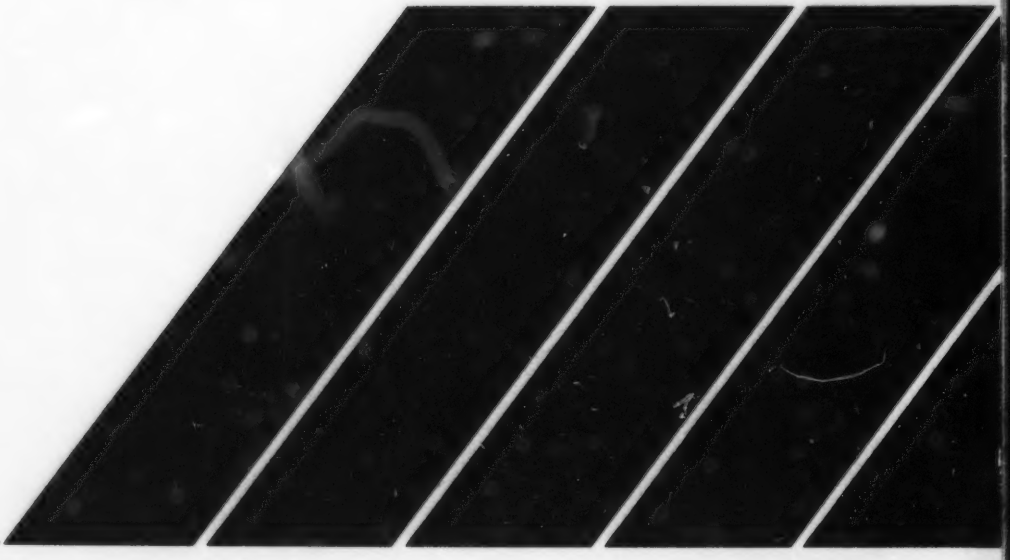
SNOW BEHAVIOUR UNDER COMPACTION FOR THE PRODUCTION OF ICE



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SNOW BEHAVIOUR UNDER COMPACTION FOR THE PRODUCTION OF ICE

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ABSTRACT

Canada experiences large amounts of snowfall during nearly half of each year. Such snow accumulations could serve as heat sinks in a variety of refrigeration or air-conditioning applications. However, the naturally low density of snow makes it necessary to carry out compactive treatments in order to minimize material handling requirements. A recent study funded by Energy, Mines and Resources, Canada investigated the effect of the addition of 10, 15 and 20% water on a weight basis to snow on compactive energy requirements. It was found that water addition of 10% significantly reduced the amount of energy required to compact snow.

The current study completes the previous study by investigating the compressive characteristics of snow at water addition levels of 0, 3, 6, 9 and 12% and initial snow temperatures of -5, -8, -11 and -18°C in three replicates. Samples were compacted to a maximum stress of 1.2 MPa using a Riehle testing machine at a constant compression rate of 102 mm/min.

Water addition significantly reduced the total energy required for compaction. At the colder temperatures of -18 and -11°C, the 12% water addition level resulted in the least amount of total stress build-up during compression. At initial snow temperatures of -8 and -5°C, the least amount of stress build-up was observed at water addition levels of 6 and 9%, respectively. When considering the work done per unit density increase per unit mass of initial wet snow, all water addition levels led to significant reductions in unit work. At snow temperatures of -18, -11 and -8°C, the 3% water addition level had significantly lower effects in reducing unit work than did the higher water addition levels. At a snow temperature of -5°C, there were no significant differences in unit work requirements between the levels of water addition. The findings support the hypothesis that the amount of water addition required for reducing the rate of stress build-up during compression increases with decreasing snow temperature.

RÉSUMÉ

Le Canada subit d'importantes chutes de neige pendant près de la moitié de l'année. De telles accumulations de neige pourraient servir de puits thermiques dans diverses applications en réfrigération et en climatisation. Cependant, la masse volumique naturellement faible de la neige exige qu'on lui fasse subir des traitements de compaction afin de minimiser les besoins en manutention. Dans le cadre d'une étude récente financée par Énergie, Mines et Ressources Canada, on a étudié l'effet de l'addition à la neige de 10, 15 et 20 % d'eau en poids sur les besoins en énergie pour la compaction. On a constaté que l'addition de 10 % d'eau réduisait de manière significative la quantité d'énergie nécessaire pour compacter la neige.

La présente étude complète la précédente en examinant les caractéristiques de compression de la neige à laquelle a été ajoutée à trois reprises 0, 3, 6, 9 et 12 % d'eau à des températures initiales de la neige de -5, -8, -11 et -18 °C. Les échantillons ont été compactés sous une contrainte maximale de 1,2 MPa au moyen d'une machine d'essai de Riehle et à un taux constant de compression de 102 mm/min.

L'addition d'eau réduisait de manière significative l'énergie totale nécessaire pour la compaction. Aux températures les plus froides de -11 et -18 °C, l'addition de 12 % d'eau entraînait la plus faible montée de pression pendant la compression. À des températures initiales de la neige de -8 et -5 °C, les plus faibles montées de pression étaient respectivement observées à l'addition de 6 et 9 % d'eau. Lorsque'est considéré le travail effectué par unité de masse volumique de neige mouillée initiale, toutes les additions d'eau entraînaient des réductions importantes du travail à effectuer. À une température de la neige de -5 °C, il n'y avait aucune différence importante entre les besoins en travail pour les diverses quantités d'eau ajoutées. Les résultats confirment l'hypothèse voulant que la quantité d'eau qu'il faut ajouter pour réduire le taux de montée de pression pendant la compression augmente à mesure que diminue la température de la neige.

INTRODUCTION

The substantial amount of snow accumulated annually during Canada's winters can serve as a significant heat sink to be used in refrigeration for produce in the agri-food sector or air-conditioning for industrial and office space. Such a concept has been put to use with the production of ice blocks as sources or supplements to refrigeration. Vigneault et al. (1988, 1989, 1990), in studies of artificial and natural ice block production for precooling and refrigerating agricultural produce, found it economically feasible to use ice blocks for refrigeration.

A way of addressing the disadvantage of the naturally low density of snow is to compact it with the least amount of energy required. In order to do so, its physical and mechanical characteristics need to be known. Snow is a very complex material and has a wide range of properties. Physically it can undergo large, irrecoverable deformation under small stresses. Some of the parameters which affect its response to deformation are initial density, rate of compression, temperature and age.

Fresh snow is thermodynamically unstable and consists of dendritic, finger-like material which evolves into larger rounded granules in a process known as metamorphosis. Snow is mechanically characterized as a highly compressible, non-linear viscoelastic material (Mellor, 1975) whose mechanical properties are influenced greatly by metamorphosis and temperature effects. One of the effects of temperature is on the cohesive and frictional strength of snow. The cohesive force between snow particles decreases with decreasing temperature. However, at very low temperatures,

the packing of snow particles can lead to frictional interaction and interlocking of grains, that is, to greater shear strength.

Yong and Metaxas (1985) studied age hardening and strain rate on confined compression. They found that aged snow required greater energy input for compaction than did fresh snow. Snow with greater initial density also required greater energy input for compaction. The relationship between energy input for compaction and age hardening tended to be linear while that between energy input for compaction and initial density tended to be exponential. They also found that confined snow strength decreased with increases in the velocity of load application.

Studies conducted to determine means of snow conditioning to affect its strength (Boonsinsuk et al., 1989) have shown the effect of ageing, surcharging, the addition of straw or sand, and snow surface heating. Heating the snow surface tended to compact the top snow layer. Heating can be considered equivalent to adding water in that it leads to snow surface melting and percolation of melt water through the snow profile with an associated restructuring and densification of the snow mass.

Boonsinsuk et al. (1989) studied the effect of preconditioning with surcharging, heating, mixing with sand, and mixing with straw on snow strength. Heating the snow surface resulted in the percolation of melt water to a depth of 400 mm, and resulted in significant increases in load bearing strength. Heating followed by ageing further increased snow load bearing strength. They found that the highest load bearing capacity was achieved by either compaction with surcharging or heat application followed by one day ageing.

The objectives of this study were to determine the compressive characteristics of snow. In particular, this study aimed to determine the amount of water addition required to minimize the energy required for compressing snow at several initial snow temperatures. This study applies specifically to the compressive characteristics of freshly fallen snow.

MATERIALS AND METHODS

Studies were conducted on the effect of water addition on the compressibility of snow at four initial temperatures. Water addition levels of 0, 3, 6, 9 and 12% on a weight basis were applied to snow samples at initial snow temperatures of -18, -11, -8 and -5°C in three replicates. 101 mm diam. by 178 mm height PVC cylinders were used for the compression studies. Snow was gathered fresh each day and temporarily stored in a freezer at ambient temperatures prevailing during snow collection. Snow was weighed and put into a rectangular plastic container for the water addition treatments. The amount of water required for the water addition level as a percentage of the snow sample was determined. Cool water at 2-3°C was added in stages of approximately 50 g until the determined amount of water was reached. At each stage the snow sample was mixed to ensure uniform distribution of added water. Samples were prepared for compaction by inserting loose snow to a third of cylinder height and gently tamping to provide contact to cylinder walls and avoid large voids. Subsequently, equivalent sample heights were inserted and tamped until the cylinder

was full. 100 mm diameter by 0.6 mm thick plexiglass stoppers were placed at the top of the samples in order to avoid sample loss and provide some insulation during compression. Initial density was determined from the sample weight in the cylinder and the cylinder volume. Final density after compaction was determined after reweighing samples and measuring the volume occupied after compression. Reweighing samples after compaction also allowed for the determination of water losses during compression.

Compressive loading was applied with a Riehle testing machine at a constant deformation rate of 102 mm/min. Load levels were determined by a Transducer Techniques SW-2K strain gage load cell with a 1.2 MPa (2000 lb) capacity. The load cell was excited using a TM-2 signal conditioner/amplifier. The load cell calibration yielded a relation of 271.5 kPa/V. Voltage output from the amplifier fed into an HP 3497A data acquisition and control (DAC) system. Digitized DAC output was fed into an HP Integral PC computer which programmed the DAC system to scan load cell output every 0.5 sec. The computer was also programmed to sound an alarm when load cell capacity was reached, at which time loading was stopped.

RESULTS AND DISCUSSION

The behaviour of snow under a constant rate of compressive loading for different initial snow temperatures is shown in Figures 1 to 4. In order to determine the effects of water addition on the compressive characteristics of snow, the rate and

total amount of stress build-up with time under each treatment were analyzed. Stress built up exponentially with time during loading. In certain cases a break in the exponential rise was observed indicating a temporary stress relaxation. This phenomenon has been observed by other researchers and is known as brittle deformation (Kinosita, 1967) or micro-fracturing (Yong and Fukue, 1977).

Results of the statistical analysis of the natural log of stress versus water addition, time and initial snow temperature are shown in Table 1. Variations of the log of stress with time for the different snow temperature and water addition treatments are shown in Figures 5 to 8. At an initial snow temperature of -18 C, each water addition level had a significantly different effect on stress build-up, with a water addition level of 3% resulting in the greatest stress build up followed by the case of no water addition. The reason for the increase in stress build-up at the 3% addition level may have been because of the small amount of water added which could have led to interparticle bonding and refrozen in the process. The 12% water addition level resulted in the least amount of total stress build-up during compression. At an initial snow temperature of -11 C, the 12% water addition level was again the most favourable in reducing stress build-up during compaction. There were no significant differences between water addition levels of 3, 6 and 9%. At initial snow temperatures of -11, -8 and -5°C, the greatest stress build-up observed was for no water addition. At initial snow temperatures of -8 and -5°C, the 6% and 9% water addition levels, respectively, were the most favourable for reduced stress build-up during compression.

Table 1. Mean values of the exponent for stress (kPa) build-up with time at each snow temperature and water addition level.

Water Addition % (w/w)	Snow Temperature °C			
	-18	-11	-8	-5
0	5.0048 a*	5.3274 a	5.0439 a	5.1974 a
3	5.0994 b	5.1888 b	4.4036 b	5.1010 b
6	4.8192 c	5.1839 b	4.3565 c	5.1209 b
9	4.9698 d	5.1724 b	4.4712 d	4.8629 c
12	4.7347 e	5.0779 c		4.9183 d

* Means with the same letter within a column are not significantly different at the 0.01 level.

The total work expended during compaction was determined as follows:

$$W=\sum_{i=0}^{n} PS\Delta x_i \qquad (1)$$

where W = work expended, kJ

n = number of time intervals to reach maximum pressure

P = pressure applied, kPa

S = area on which pressure is applied, m^2

Δx_1 = displacement of the surface during one time interval, m.

When considering the work done per unit density increase per unit mass of initial wet snow (Table 2), all water addition levels led to significant reductions in unit work for the four snow temperatures studied. At snow temperatures of -18, -11 and -8°C, the 3% water addition level had significantly lower effects in reducing unit work than did the higher water addition levels. At a snow temperature of -5°C, there were no significant differences in unit work requirements between the levels of water addition. The findings obtained for density increases and unit work required for compaction were similar to those obtained in a similar study in the previous year where density increases of 0.32 to 0.38 Mg/m^3 and unit work per unit mass of wet snow from 750 to 800 kJ were observed at a water addition level of 10% (Gameda and Vigneault, 1991).

Table 2. Mean work values per unit density increase per unit mass of wet snow ($kJ/\Delta\rho/kg$) at each snow temperature and water addition level.

Water Addition % (w/w)	Snow Temperature °C			
	-18	-11	-8	-5
0	1531.4 a	1465.2 a	1484.2 a	1332.0 a
3	1289.8 b	894.3 b	893.0 b	749.1 b
6	780.0 c	769.5 b c	642.9 c	754.5 b
9	756.5 c	728.4 c	644.9 c	680.4 b
12	707.8 c	736.2 c		725.5 b

It was noted during experimentation that at an initial snow temperature of -5°C and water addition level of 9% water loss during compression exceeded the amount of water added indicating that some melting of the sample was occurring. Similarly, at an initial snow temperature of -8°C water loss in excess of that applied was observed for water addition levels of 6 and 9%. This suggests that moisture additions of slightly less than 6% are sufficient to reduce compactive energy requirements without excessive snow loss due to melting for snow temperatures greater than -8°C.

The relationship for stress build-up with time, initial snow temperature and water addition level can be described as follows:

$$\sigma = k\ e^{(a.time + b.temp - c.mc)} \qquad (2)$$

where σ = stress build-up, kPa

time = time taken to reach a stress of 1.1 MPa, sec

temp = initial snow temperature, C

mc = water addition level, %

k,a,b,c = constants

The relationship at each snow temperature level is:

$$\sigma = k\ e^{(a.time - c.mc)} \qquad (3)$$

The values for the constants for the above equations are given in Table 3.

Table 3. Constants for the relationship between stress build-up, elapsed time, initial snow temperature and added water content.

Snow Temperature °C	k	a	b	c
- 18	14.73	0.0879		0.0372
- 11	26.64	0.0904		0.0331
- 8	10.69	0.0830		0.0546
- 5	21.65	0.0918		0.0504
Overall	18.99	0.0825	0.0059	0.0248

As can be seen from Table 3, the effect of water was somewhat more pronounced at -8 and -5°C than at -18 or -11°C. The constant associated with time indicated that there were no differences in stress build-up related to time. The rate of stress build up due to time and water addition was not as pronounced as the intercept of the log of stress axis, k, which indicates the initial resistance to compression. It can be seen from k values that the least initial resistance to compaction was at a snow temperature of -8°C and that the highest was at -11°C.

SUMMARY AND CONCLUSIONS

This study consisted of an investigation into the modification of the compressive characteristics of snow by the addition of water prior to compaction. Snow samples at initial temperatures of -18, -11, -8 and -5 were treated with 0, 3, 6, 9 and 12% water addition (w/w). The samples were subjected to compression at a rate of 102 mm/min to a maximum stress level of 1.2 MPa. The behaviour of snow showed an exponential stress build-up under a constant compression rate. This build-up was significantly affected by water addition. At initial snow temperatures of -18°C water addition levels of 6 to 12% effected significant reductions in stress build-up and work required for unit increase in density. The 3% water addition level increased stress build-up and marginally decreased unit work requirements over that of no water addition. At snow temperatures of -11°C and greater all water addition levels resulted in significant reductions in the work required for compaction. Water losses at snow temperatures of -8 and -5°C indicate that water additions of less than 6% should be utilized for snow temperatures greater than -8 C.

IMPLICATIONS FOR A SNOW COMPACTION MACHINE

The results of this study indicate that it would be feasible to compact snow with a snow compaction machine for the preparation of snow blocks. The requirements for a snow compacting apparatus would be (i) a bin for mixing snow

with water; (ii) a piston-type compactive set-up with a compaction chamber similar to that used in the compaction of hay bales; (iii) a conveying device to bring uncompacted snow and water mixtures to the compaction chamber and another one to take compacted snow blocks to a storage area.

The mixing bin should be equipped with misting nozzles to provide water as well as kneading-type paddles to mix snow and water. The bin should be insulated, and the paddles as well as conveying devices should be coated with a non-sticky, plastic coating. A rectangular compacting chamber is recommended so that the blocks produced can easily be handled during storage and shipping. The compaction chamber should have small perforations for the evacuation of excess water.

For production purposes, it is important to provide for a system that can handle a wide range of snow temperatures without the need to determine the amount of water addition required for each snow load. It is suggested that a water addition level of 6% be used for all cases. This would minimize the amount of snow loss due to melting at snow temperatures greater than -8°C while also providing sufficient moisture for enhancing snow compressibility at temperatures less than -8°C.

As an example of the work required to compact snow with such a machine, a volume of 1 m^3 and a water addition level of 6% can be considered. Taking an initial snow density of 0.4 Mg/m^3 (400 kg/m^3) and unit work requirement of 700 $kJ/\Delta\rho/kg$, the total amount of work required to compact a 1 m^3 volume of snow to a density of 0.8 Mg/m^3 under the given conditions would be 112 MJ. Total work required for each snow temperature and water addition level is given in Table A3 of the Appendix.

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FIGURES

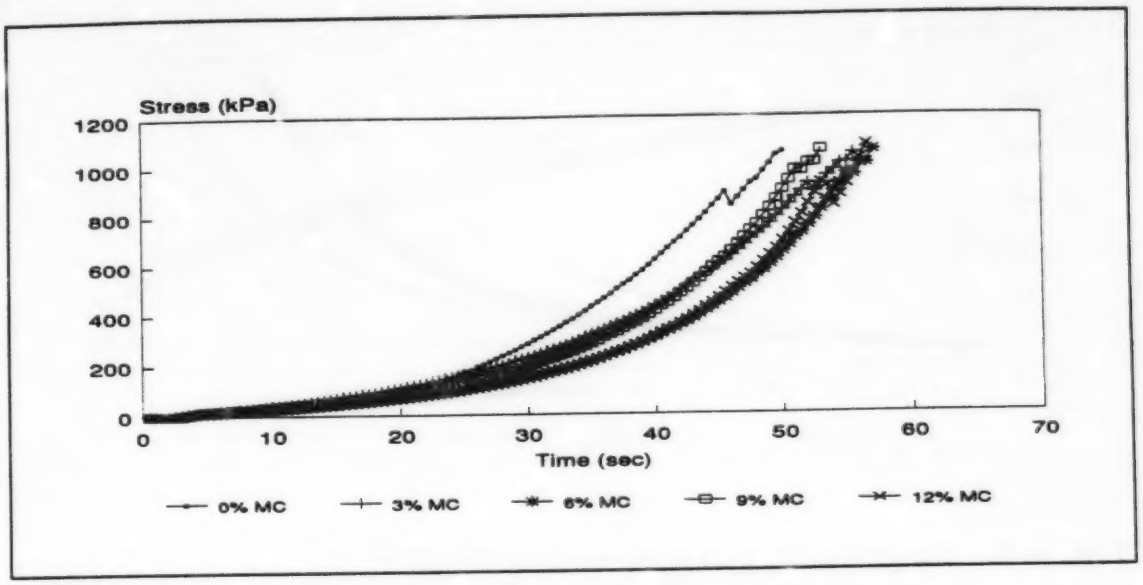

Figure 1 Stress build-up at a snow temperature of -18 C.

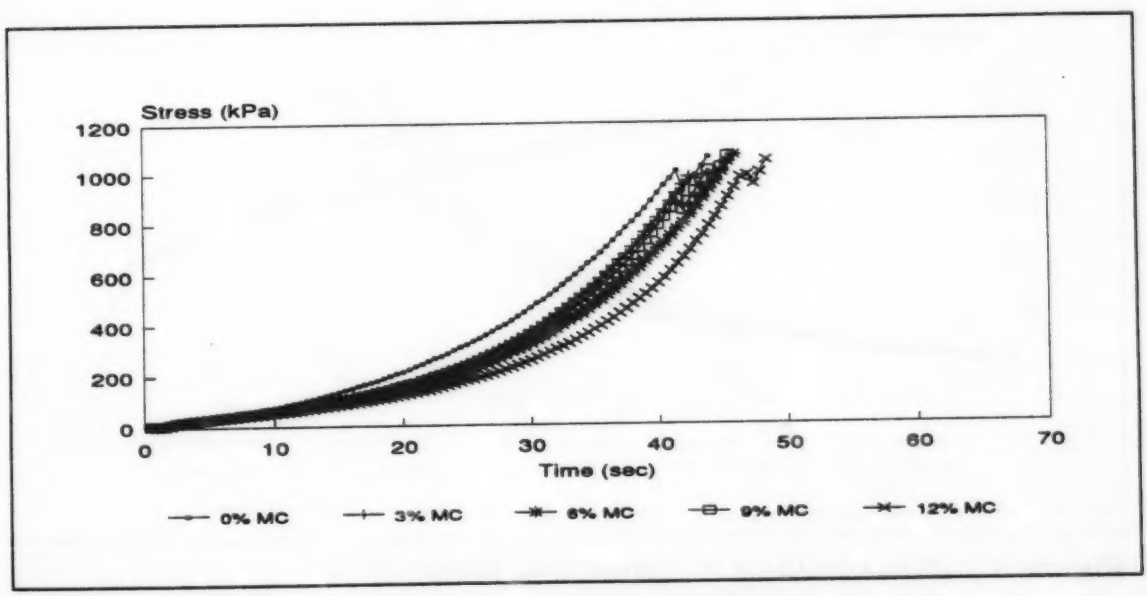

Figure 2 Stress build-up at a snow temperature of -11 C.

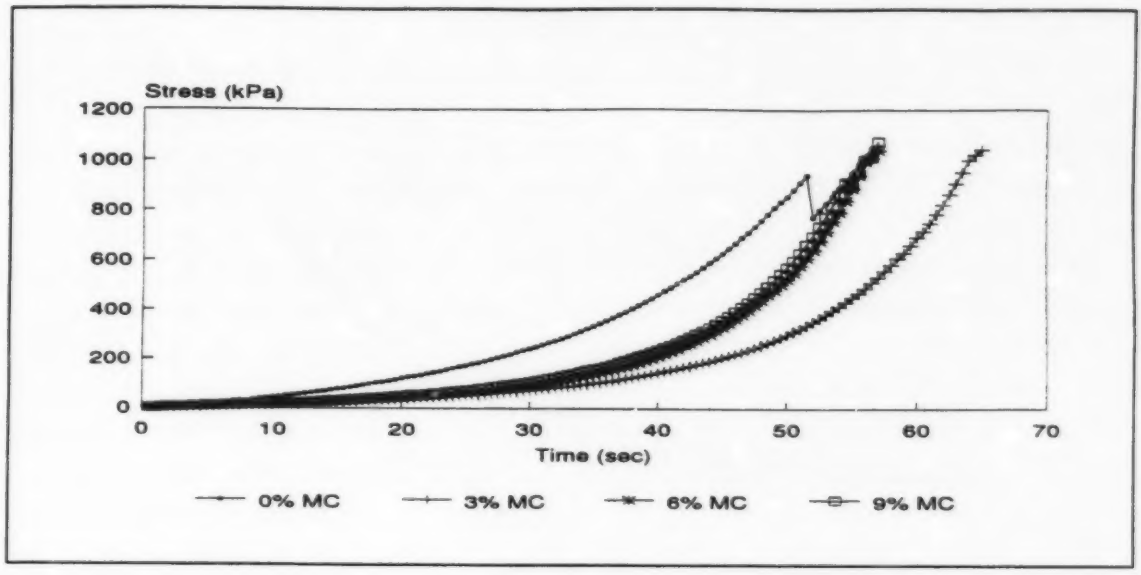

Figure 3 Stress build-up at a snow temperature of -8 C.

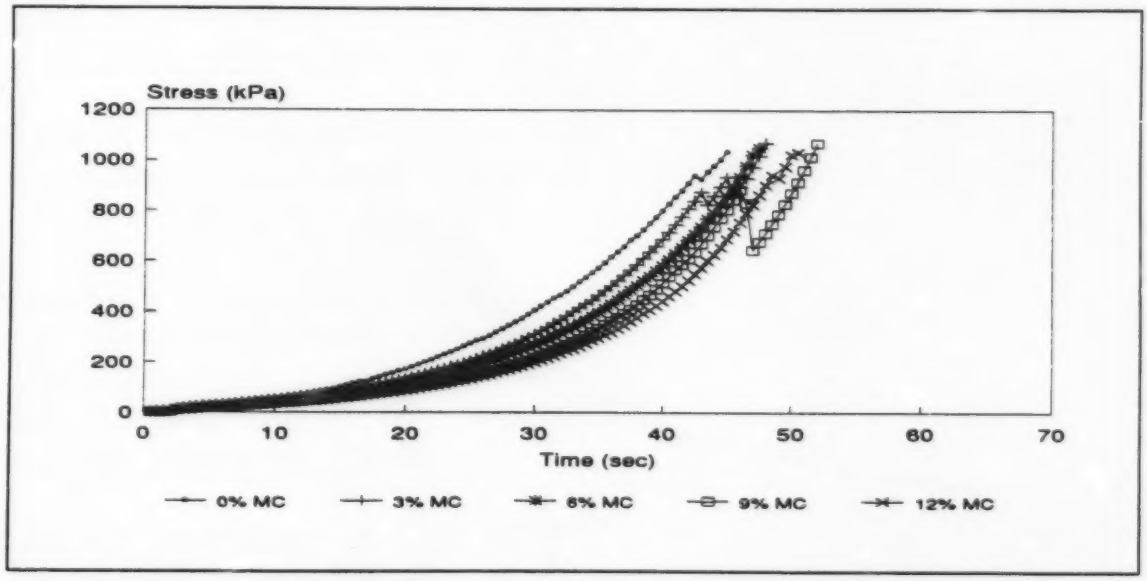

Figure 4 Stress build-up at a snow temperature of -5 C.

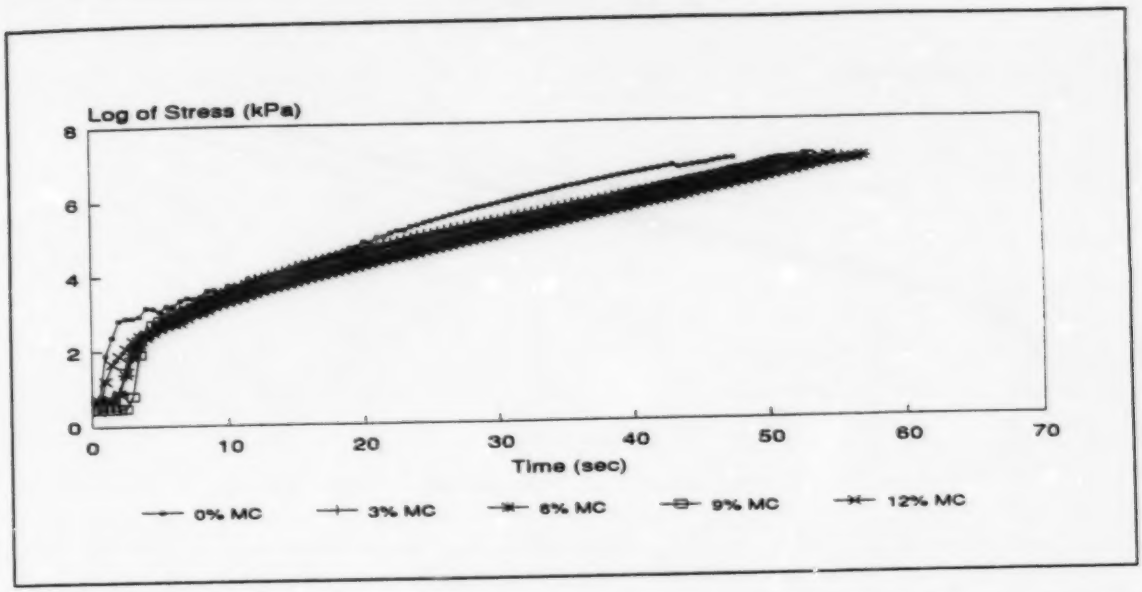

Figure 5 Log of stress build-up at a snow temperature of -18 C.

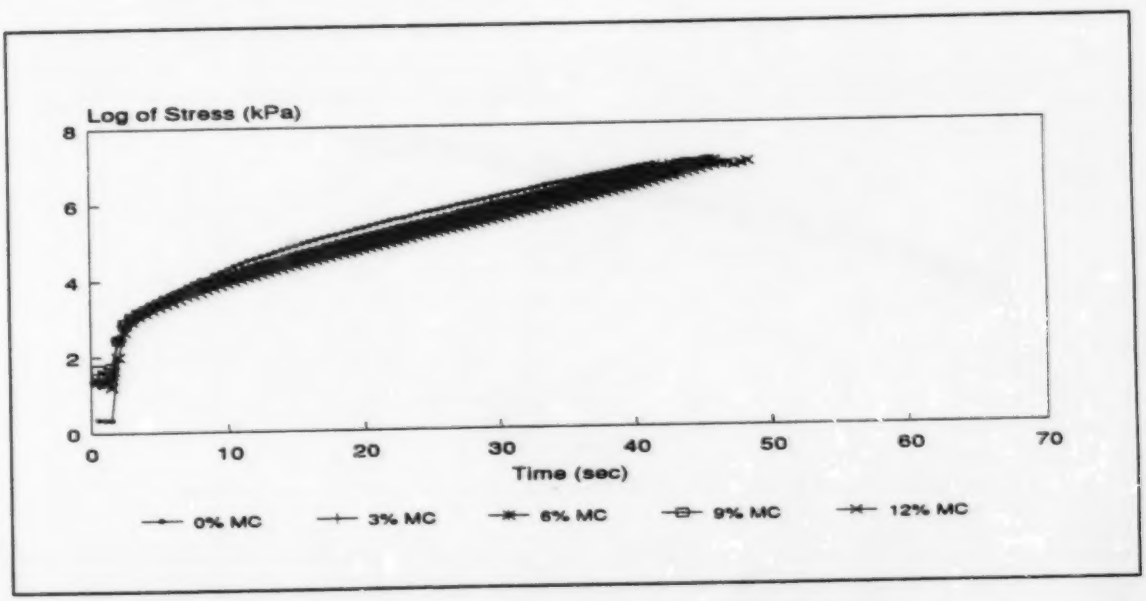

Figure 6 Log of stress build-up at a snow temperature of -11 C.

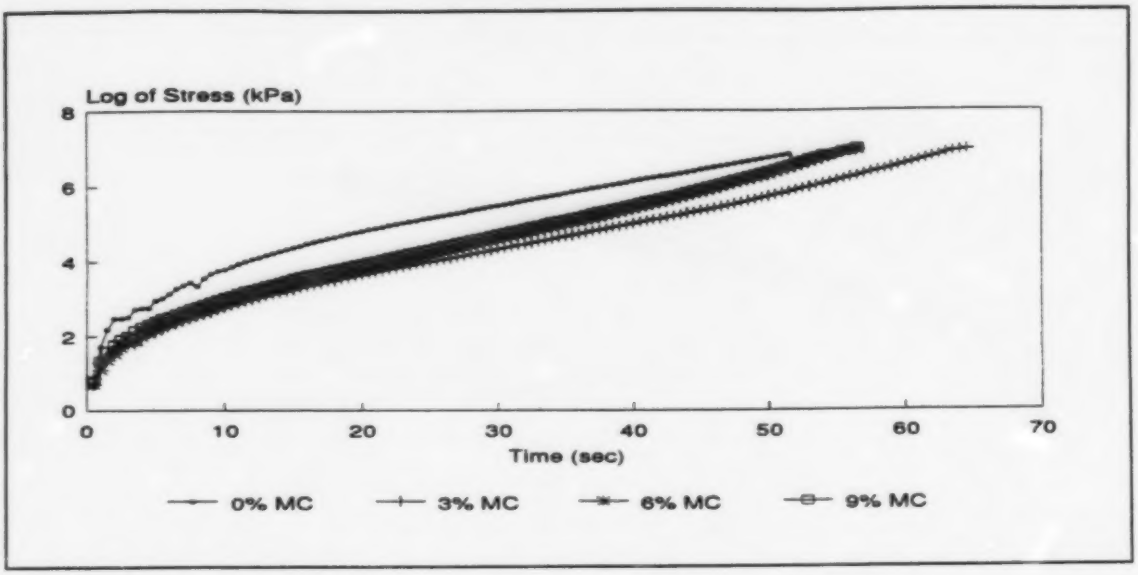

Figure 7 Log of stress build-up at a snow temperature of -8 C.

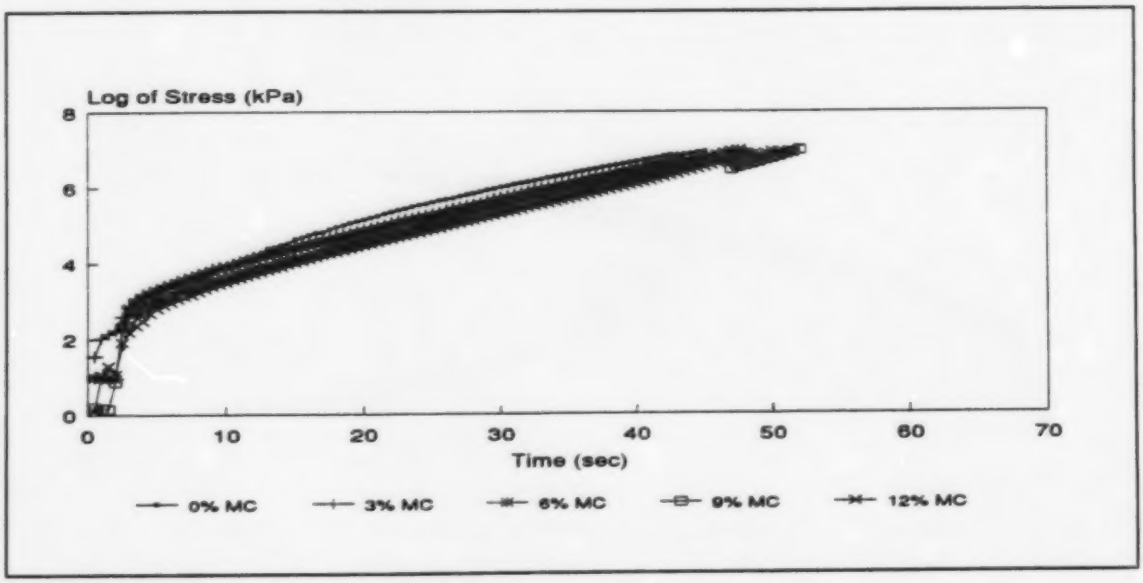

Figure 8 Log of stress build-up at a snow temperature of -5 C.

APPENDIX A

Table A1. Percent water loss, density increases, total and unit work, and unit work per unit mass of snow.

Temp C	MC %	Snow Wt1	Snow Wt2	MC Wt	MC Loss	%Loss	Den1	Den2	Delden	Work KJ	Unit Wk KJ/Δρ	UWk/Wt1 ------- KJ/Δρ/Kg -------	UWk/Wt2	UWk/dsn
-18	0	460.5	460.0	0.0	0.5	0.0	0.33	0.59	0.26	187.5	727.5	1579.8	1581.5	1579.8
-18	0	470.4	470.1	0.0	0.3	0.0	0.34	0.60	0.26	185.8	705.0	1498.7	1499.7	1498.7
-18	0	458.5	458.1	0.0	0.4	0.0	0.33	0.61	0.28	191.5	695.0	1515.7	1517.0	1515.7
-18	12	616.1	562.6	73.9	53.5	72.4	0.45	0.82	0.37	164.8	446.1	724.0	792.9	822.8
-18	12	570.9	526.1	68.5	44.8	65.4	0.41	0.80	0.39	169.2	437.8	766.8	832.1	871.4
-18	12	639.8	592.2	76.8	47.6	62.0	0.46	0.88	0.42	168.2	404.7	632.5	683.3	718.7
-18	9	619.2	605.5	55.7	13.7	24.6	0.45	0.78	0.33	189.2	573.7	926.5	947.5	1018.1
-18	9	607.1	577.0	54.6	30.1	55.1	0.44	0.84	0.40	176.8	445.5	733.8	772.1	806.4
-18	9	662.4	626.8	59.6	35.6	59.7	0.48	0.93	0.45	181.9	403.6	609.3	643.9	669.6
-18	6	563.7	538.0	33.8	25.7	76.0	0.41	0.81	0.40	184.0	460.0	816.1	855.1	868.2
-18	6	568.7	552.5	34.1	16.2	47.5	0.41	0.81	0.40	194.3	487.4	857.1	882.2	911.8
-18	6	580.4	553.5	34.8	26.9	77.2	0.42	0.84	0.42	177.7	421.8	726.7	762.0	773.1
-18	3	452.7	452.5	13.6	0.2	1.5	0.33	0.68	0.35	212.7	604.3	1335.0	1335.5	1376.2
-18	3	481.4	481.2	14.4	0.2	1.4	0.35	0.68	0.33	214.7	644.4	1338.6	1339.2	1380.0
-18	3	485.4	485.2	14.6	0.2	1.4	0.35	0.72	0.37	214.0	580.4	1195.7	1196.2	1232.7
-11	0	519.0	518.4	0.0	0.6	0.0	0.38	0.63	0.25	188.3	748.5	1442.2	1443.8	1442.2
-11	0	534.1	533.6	0.0	0.5	0.0	0.39	0.62	0.23	199.0	868.6	1626.3	1627.8	1626.3
-11	0	524.1	523.8	0.0	0.3	0.0	0.38	0.65	0.27	190.2	695.5	1327.1	1327.9	1327.1
-11	12	717.1	644.1	86.1	73.0	84.8	0.52	0.84	0.32	173.9	548.5	764.9	851.6	869.2
-11	12	724.2	648.0	86.9	76.2	87.7	0.53	0.84	0.32	172.9	545.5	753.2	841.8	855.9
-11	12	694.4	639.2	83.3	55.2	66.2	0.50	0.86	0.35	169.7	479.4	690.4	750.0	784.6
-11	9	685.5	669.0	61.7	16.5	26.7	0.50	0.84	0.35	184.9	534.4	779.6	798.8	856.7
-11	9	747.9	690.4	67.3	57.5	85.4	0.54	0.84	0.30	168.1	556.4	744.0	806.0	817.6
-11	9	716.6	666.2	64.5	50.4	78.1	0.52	0.87	0.35	164.1	474.1	661.6	711.6	727.0
-11	6	660.4	653.8	39.6	6.6	16.7	0.48	0.83	0.35	188.2	532.4	806.2	814.4	857.7
-11	6	668.2	654.9	40.1	13.3	33.2	0.48	0.84	0.36	191.0	533.8	798.9	815.1	849.9
-11	6	662.1	643.7	39.7	18.4	46.3	0.48	0.86	0.38	178.6	465.8	703.5	723.6	748.4
-11	3	625.5	625.1	18.8	0.4	2.1	0.45	0.76	0.31	181.2	582.6	931.4	932.0	960.2
-11	3	609.3	609.0	18.3	0.3	1.6	0.44	0.78	0.33	177.8	533.2	875.0	875.5	902.1
-11	3	603.1	602.5	18.1	0.6	3.3	0.44	0.78	0.34	178.5	528.7	876.6	877.5	903.8
-8	0	420.2	419.7	0.0	0.5	0.0	0.30	0.62	0.31	212.6	682.8	1624.9	1626.9	1624.9
-8	0	430.0	429.7	0.0	0.3	0.0	0.31	0.64	0.33	214.3	656.5	1526.6	1527.7	1526.6
-8	0	406.4	406.1	0.0	0.3	0.0	0.29	0.69	0.40	211.2	528.7	1301.0	1302.0	1301.0
-8	9	577.9	524.2	52.0	53.7	103.2	0.42	0.82	0.40	155.1	389.2	673.5	742.5	740.1
-8	9	497.6	456.5	44.8	41.1	91.8	0.36	0.84	0.48	153.3	321.5	646.1	704.3	710.0
-8	9	582.8	522.1	52.5	60.7	115.7	0.42	0.86	0.43	155.8	358.6	615.2	686.7	676.1
-8	6	544.2	493.1	32.7	51.1	156.5	0.39	0.83	0.44	153.8	352.1	647.0	714.1	688.3
-8	6	528.2	475.9	31.7	52.3	165.0	0.38	0.81	0.43	147.2	342.0	647.5	718.7	688.8
-8	6	549.4	489.0	33.0	60.4	183.2	0.40	0.82	0.43	148.5	348.5	634.3	712.7	674.8
-8	3	372.0	371.6	11.2	0.4	3.6	0.27	0.80	0.53	174.1	328.7	883.5	884.4	910.8
-8	3	360.4	358.1	10.8	2.3	21.3	0.26	0.77	0.51	176.5	346.7	962.0	968.1	991.7
-8	3	384.9	374.4	11.5	10.5	90.9	0.28	0.81	0.53	168.9	320.9	833.6	857.0	859.4

Table A1. (cont'd).

Temp C	MC %	Snow Wt1	Snow Wt2	MC Wt	MC Loss	%Loss	Den1	Den2	Delden	Work KJ	Unit Wk KJ/Δρ	UWk/Wt1 -------	UWk/Wt2 KJ/Δρ/Kg	UWk/dsn -------
-5	0	531.4	531.3	0.0	0.1	0.0	0.39	0.64	0.25	185.9	737.6	1388.1	1388.4	1388.1
-5	0	533.4	533.2	0.0	0.2	0.0	0.39	0.65	0.27	198.6	748.3	1402.9	1403.5	1402.9
-5	0	555.7	555.2	0.0	0.5	0.0	0.40	0.68	0.28	184.9	669.6	1205.0	1206.1	1205.0
-5	12	732.4	648.3	87.9	84.1	95.7	0.53	0.84	0.31	166.5	534.7	730.0	824.7	829.6
-5	12	688.3	616.7	82.6	71.6	86.7	0.50	0.83	0.33	172.8	526.5	765.0	853.8	869.3
-5	12	710.5	630.8	85.3	79.7	93.5	0.52	0.84	0.32	155.9	484.2	681.4	767.5	774.4
-5	9	731.5	641.9	65.8	89.6	136.1	0.53	0.84	0.31	163.6	523.5	715.6	815.5	786.4
-5	9	757.0	652.5	68.1	104.5	153.4	0.55	0.85	0.30	162.3	542.8	717.0	831.8	787.9
-5	9	702.7	595.4	63.2	107.3	169.7	0.51	0.87	0.36	155.8	427.6	608.5	718.2	668.7
-5	6	669.8	641.3	40.2	28.5	70.9	0.49	0.83	0.35	183.0	526.3	785.7	820.6	835.8
-5	6	676.8	645.8	40.6	31.0	76.3	0.49	0.84	0.35	182.7	524.2	774.6	811.8	824.0
-5	6	691.6	647.3	41.5	44.3	106.8	0.50	0.85	0.35	169.5	486.3	703.1	751.2	748.0
-5	3	665.5	650.6	20.0	14.9	74.6	0.48	0.84	0.35	172.8	487.8	733.0	749.8	755.7
-5	3	679.4	661.7	20.4	17.7	86.8	0.49	0.81	0.32	173.0	546.3	804.1	825.6	828.9
-5	3	699.0	662.0	21.0	37.0	176.4	0.51	0.86	0.35	175.5	496.5	710.3	750.0	732.3

Table A2. Stress build-up with time at each snow temperatue and water addition level.

TMP	TIME	Stress build-up (kPa) at indicate water addition levels (% w/w)														
		0	0	0	12	12	12	9	9	9	6	6	6	3	3	3
°C	sec															
-18	0.5															
-18	1.0															
-18	1.5														3.77	
-18	2.0										3.12	2.12			9.45	2.63
-18	2.5				1.68		1.93				5.43	4.53			13.17	6.05
-18	3.0		1.06	3.39	4.67		4.40	2.06		2.63	8.80	7.82	2.44	5.00	14.82	9.34
-18	3.5		8.20	10.64	7.60		7.22	7.33	5.10	7.90	10.94	10.56	5.29	8.53	14.63	11.84
-18	4.0	5.84	14.12	12.22	9.42		9.18	13.14	8.55	12.44	12.41	11.97	7.52	9.99	16.73	13.52
-18	4.5	14.82	19.36	15.97	10.81	2.31	10.67	16.94	10.83	17.11	13.77	13.71	8.93	11.21	18.98	15.67
-18	5.0	16.45	18.87	17.97	11.43	5.67	12.11	19.22	11.84	18.71	15.04	15.21	10.02	11.89	21.48	16.02
-18	5.5	20.09	18.71	14.47	12.52	7.09	13.49	21.23	13.25	20.34	15.72	16.70	11.11	13.44	24.30	17.54
-18	6.0	19.25	20.26	16.64	13.63	8.20	13.82	23.19	14.58	22.24	17.05	16.73	12.16	14.39	26.99	22.94
-18	6.5	23.73	24.95	21.99	14.82	9.26	15.10	21.48	15.88	23.87	14.69	19.14	12.84	16.43	29.81	20.72
-18	7.0	26.36	21.83	21.18	16.07	9.80	16.45	23.70	17.21	24.60	18.44	20.53	13.90	18.49	31.66	22.05
-18	7.5	18.08	22.92	22.45	17.43	10.86	17.87	26.28	18.60	26.17	21.88	21.86	14.99	20.69	34.59	24.06
-18	8.0	19.09	29.87	24.84	18.84	11.92	19.33	29.76	20.01	26.99	22.51	22.64	16.16	22.86	37.55	26.42
-18	8.5	21.31	25.66	26.26	20.36	13.01	20.88	33.21	21.50	29.13	24.17	23.43	17.30	25.06	40.73	29.11
-18	9.0	23.46	29.81	31.85	21.97	14.04	22.40	35.38	23.30	31.20	26.07	27.56	18.49	26.55	43.93	31.90
-18	9.5	25.79	40.16	25.50	23.51	15.18	24.19	37.55	25.06	33.42	27.78	29.51	19.28	28.89	47.30	34.84
-18	10.0	25.55	36.00	27.67	25.17	16.35	25.90	39.80	26.83	35.79	29.92	30.71	20.53	31.31	49.50	36.76
-18	10.5	27.91	34.37	31.82	26.88	17.54	27.64	42.09	28.78	38.23	30.55	32.61	21.86	33.83	52.97	39.70
-18	11.0	30.55	43.99	37.44	27.31	18.79	28.35	44.39	29.24	39.48	32.23	34.56	23.27	36.41	56.58	42.76
-18	11.5	37.25	41.35	34.02	29.05	20.09	30.25	46.84	31.14	42.03	34.05	36.68	24.90	39.07	60.41	45.91
-18	12.0	32.85	33.70	38.34	30.68	21.48	32.31	49.28	32.96	44.37	36.03	38.77	26.23	41.84	64.21	49.09
-18	12.5	38.42	51.59	36.14	32.53	22.94	34.29	51.75	35.03	47.03	37.96	40.94	27.86	44.69	68.15	52.38
-18	13.0	38.42	41.46	43.93	34.46	24.44	36.38	54.41	37.14	49.82	39.91	43.25	29.51	46.24	70.76	54.60
-18	13.5	38.69	50.10	37.93	36.41	25.96	38.58	57.05	39.29	52.62	41.98	45.53	30.41	49.25	73.93	58.00
-18	14.0	48.00	59.25	44.12	38.42	27.53	40.78	58.08	41.52	54.79	44.04	46.78	32.15	52.27	78.22	61.55
-18	14.5	37.88	46.86	45.02	40.54	29.16	43.12	60.82	43.90	57.72	45.18	49.23	33.91	55.55	82.68	65.30
-18	15.0	41.11	64.89	48.00	42.68	30.79	45.56	63.73	46.27	60.87	47.33	51.72	35.87	58.78	87.05	69.07
-18	15.5	43.20	71.57	47.71	44.88	32.58	47.95	66.68	48.28	64.00	49.58	54.39	37.77	62.18	91.50	72.96
-18	16.0	47.60	51.24	56.75	47.22	34.35	50.45	69.73	51.15	67.26	52.00	57.05	39.72	65.76	94.54	77.06
-18	16.5	50.23	63.92	47.05	49.58	36.17	53.08	72.93	54.14	70.70	54.33	59.82	41.05	69.32	99.35	81.13
-18	17.0	53.79	88.95	52.02	51.94	38.12	53.71	74.94	56.94	74.18	56.80	62.64	43.12	71.19	102.09	83.41
-18	17.5	49.06	97.94	50.42	54.49	40.10	56.37	78.22	60.01	77.79	58.40	65.57	45.23	74.94		

-18 18.0	54.03	106.05	65.71	57.02	42.14	59.27	81.70	60.71	81.62	60.98	67.12	47.52	78.41	107.47	87.75
-18 18.5	52.92	114.23	57.70	59.60	44.28	62.18	85.18	63.73	85.50	63.35	70.16	49.77	82.24	111.76	92.26
-18 19.0	57.94	118.38	66.90	62.39	46.48	65.11	88.79	66.49	87.02	66.06	73.31	52.19	86.29	117.16	96.71
-18 19.5	59.00	126.66	74.48	65.22	48.74	68.21	92.83	69.67	91.12	68.91	76.57	53.81	90.58	122.67	101.30
-18 20.0	73.96	135.41	64.21	68.04	51.13	71.38	96.44	73.12	94.90	71.90	79.91	56.39	94.81	128.62	106.05
-18 20.5	68.12	144.18	74.40	71.08	53.57	74.64	100.65	76.49	99.19	74.88	83.41	58.87	99.24	134.51	109.31
-18 21.0	69.75	152.92	82.16	74.18	56.10	78.17	105.51	80.07	103.86	77.98	85.69	61.61	102.15	140.48	114.23
-18 21.5	78.88	162.34	86.83	77.41	58.76	81.73	109.77	83.84	108.44	81.32	89.33	64.35	106.76	144.31	119.33
-18 22.0	81.51	171.57	88.76	80.78	61.44	85.31	114.17	87.89	113.17	84.58	92.99	67.17	110.94	142.03	124.68
-18 22.5	102.58	181.29	105.29	84.17	64.27	89.25	119.03	91.42	118.33	86.34	96.93	69.16	115.86	149.66	130.00
-18 23.0	74.78	190.71	114.63	87.67	67.20	90.14	120.12	95.55	123.43	89.79	100.92	72.17	120.26	157.97	135.54
-18 23.5	109.88	201.17	123.32	89.52	70.19	94.14	124.63	99.67	126.64	93.54	105.05	75.35	125.36	164.89	141.27
-18 24.0	100.65	211.65	132.26	93.24	73.28	97.80	129.60	104.05	126.04	93.97	109.37	78.71	130.63	172.31	147.05
-18 24.5	122.48	222.37	141.16	97.23	76.60	101.96	134.67	108.69	134.10	100.35	113.77	82.05	136.25	177.68	150.07
-18 25.0	135.32	233.21	150.31	101.25	79.93	105.76	139.83	109.83	140.05	104.94	118.33	85.56	141.79	185.09	156.10
-18 25.5	121.56	244.04	159.63	105.43	83.38	110.24	145.48	114.61	146.62	107.74	123.13	87.94	147.57	190.80	162.18
-18 26.0	145.86	255.82	169.18	109.86	87.02	114.93	151.24	119.71	153.00	112.03	127.99	91.66	151.34	198.56	168.61
-18 26.5	153.68	267.47	178.85	114.31	90.74	119.79	157.10	124.87	159.52	116.43	133.07	95.55	157.26	206.44	175.13
-18 27.0	166.39	279.45	189.09	118.95	94.60	124.82	163.29	130.19	166.03	121.04	138.42	99.67	163.37	214.44	182.00
-18 27.5	178.55	292.04	199.19	123.89	98.72	130.22	169.48	135.95	173.15	125.71	143.82	103.80	169.92	219.60	186.40
-18 28.0	190.14	304.62	209.61	128.89	99.70	135.60	176.03	141.71	176.87	130.55	149.47	108.17	176.41	227.97	193.40
-18 28.5	202.72	314.42	220.64	134.08	103.94	141.33	182.95	147.62	184.25	135.73	155.36	111.05	182.68	236.30	199.70
-18 29.0	215.26	327.56	231.60	139.75	107.79	144.23	184.63	153.98	192.29	140.92	161.39	115.80	190.04	245.21	207.17
-18 29.5	228.02	341.54	242.85	145.32	112.38	150.20	191.50	160.09	200.22	143.71	167.64	120.93	197.04	254.01	214.63
-18 30.0	240.86	355.80	253.22	151.13	116.51	156.61	201.47	166.96	208.66	149.17	173.88	125.66	200.95	263.16	222.70
-18 30.5	254.66	370.00	264.95	157.32	121.40	162.99	211.32	173.99	217.57	154.87	180.70	130.93	208.28	269.32	230.57
-18 31.0	268.23	385.28	275.75	163.59	126.55	169.83	221.15	181.18	226.47	160.96	187.67	136.25	215.99	278.69	238.77
-18 31.5	282.24	400.22	288.05	169.97	131.88	177.03	231.12	188.62	235.95	167.12	192.26	142.00	223.89	288.54	244.31
-18 32.0	296.66	415.94	299.38	177.08	137.28	184.25	240.08	196.55	240.95	173.47	199.57	147.81	232.12	298.78	252.86
-18 32.5	311.32	432.53	312.63	184.28	143.17	191.83	249.04	204.59	250.86	180.26	207.17	150.94	240.43	306.68	261.80
-18 33.0	326.39	449.15	324.55	191.64	149.06	195.85	253.52	212.95	261.47	185.75	215.26	157.07	246.02	317.59	271.06
-18 33.5	341.95	465.98	338.56	199.65	155.28	203.86	263.18	221.94	272.28	189.33	223.46	163.40	254.82	328.59	280.53
-18 34.0	357.78	483.44	353.19	207.74	161.88	212.65	273.50	231.06	283.57	191.94	231.96	170.35	263.97	340.46	290.20
-18 34.5	373.66	501.22	368.21	216.07	168.56	221.37	283.55	240.54	295.36	204.37	240.95	177.33	273.47	351.89	300.52
-18 35.0	390.80	519.60	383.33	225.12	175.56	230.63	294.54	250.67	307.49	209.80	250.10	184.61	283.11	364.05	310.75
-18 35.5	407.63	539.45	399.19	234.16	183.00	240.40	306.57	260.87	320.01	219.28	254.93	192.40	293.19	377.00	316.13
-18 36.0	420.74	559.00	415.07	243.74	190.20	250.48	318.79	271.55	333.42	228.24	264.49	200.27	299.70	389.76	326.85
-18 36.5	438.61	579.34	431.50	253.84	198.21	260.82	331.09	282.98	347.05	233.94	274.50	208.44	310.16	403.01	337.99
-18 37.0	457.45	599.67	449.01	256.31	206.79	271.93	344.26	294.54	352.35	242.93	285.26	217.35	320.93	416.92	349.66
-18 37.5	476.24	620.58	465.98	266.71	215.31	282.92	357.51	306.46	366.41	252.32	296.09	220.72	332.37	422.29	361.47
-18 38.0	495.68	642.22	472.69	276.38	224.19	294.62	371.41	319.36	381.81	262.31	307.33	229.76	343.96	436.66	373.61
-18 38.5	515.86	665.30	490.85	287.67	233.83	307.58	386.21	322.48	397.61	272.58	314.88	239.26	355.74	449.99	381.65

-18 39.0	536.30	687.81	507.47	298.29	243.58	319.82	401.22	335.76	413.85	283.17	326.91	249.31	363.78	465.14	394.92
-18 39.5	557.05	711.32	526.26	310.51	253.71	333.13	416.75	349.80	430.98	290.36	339.23	259.57	376.11	480.78	406.25
-18 40.0	579.12	735.90	546.51	323.60	264.51	347.27	433.29	364.13	448.36	301.63	352.54	270.27	389.25	497.58	419.74
-18 40.5	600.87	760.17	566.74	337.01	275.59	361.74	449.99	379.07	466.63	313.47	365.92	281.75	402.85	513.79	433.75
-18 41.0	623.70	785.77	587.62	347.52	287.13	37[illegible]7	467.17	395.11	476.19	326.23	379.96	293.35	416.70	531.39	448.68
-18 41.5	647.22	812.27	609.94	362.01	293.16	390.58	485.75	411.40	495.47	340.13	389.41	305.40	431.03	542.90	463.54
-18 42.0	652.92	839.51	631.47	375.43	305.51	406.87	504.40	428.10	516.24	353.76	404.32	318.30	446.16	561.55	479.17
-18 42.5	677.14	867.09	654.63	390.99	316.89	424.46	524.03	446.21	537.28	362.42	419.77	323.38	461.44	580.56	495.36
-18 43.0	701.90	896.23	666.25	407.87	330.27	442.30	544.83	464.51	559.35	376.73	436.19	336.60	469.54	600.71	511.97
-18 43.5	727.51	925.33	690.52	425.03	344.58	460.87	565.98	483.63	582.79	391.72	452.97	350.61	485.39	620.69	528.81
-18 44.0	753.22	955.12	712.65	443.04	359.03	480.78	587.95	504.07	607.01	407.87	470.54	365.60	502.09	641.52	547.11
-18 44.5	780.67	987.16	737.80	462.18	374.23	501.20	611.21	524.87	632.20	420.07	489.19	380.86	519.60	663.54	565.22
-18 45.0	807.93	1018.00	761.28	481.81	390.61	522.48	634.70	546.54	645.45	436.76	508.01	396.66	537.25	685.66	584.12
-18 45.5	835.62	1050.53	788.24	502.44	407.14	545.29	643.80	569.81	672.22	454.14	527.67	407.44	555.69	697.83	589.41
-18 46.0	864.65		813.50	524.49	424.52	568.69	668.50	593.51	697.83	472.88	548.57	424.49	574.83	721.31	608.93
-18 46.5	893.76		842.28	547.24	433.59	593.24	695.11	618.08	727.02	491.72	569.83	442.33	594.62	745.48	629.32
-18 47.0	923.41		872.52	556.04	452.19	620.47	721.59	644.64	759.06	511.46	591.99	461.53	614.74	770.92	650.91
-18 47.5	954.36		902.55	580.02	469.40	626.42	742.52	671.63	792.37	532.45	598.26	481.37	636.63	796.96	673.42
-18 48.0	962.23		926.09	606.33	489.63	653.73	771.27	692.91	819.06	553.98	621.69	501.68	645.07	823.19	695.71
-18 48.5	993.38		958.32	633.15	511.30	683.66	801.63	722.70	856.07	565.52	646.24	514.72	667.58	841.81	710.02
-18 49.0	1026.85		987.27	661.72	533.72	714.53	833.18	755.36	895.71	588.30	673.15	536.57	690.44	870.05	733.59
-18 49.5	1060.44		1019.96	693.16	556.99	739.48	865.63	789.28	936.28	609.91	700.33	559.30	714.23	899.67	757.97
-18 50.0			1055.06	726.09	582.00	774.37	900.44	824.52	978.82	634.75	728.97	583.76	732.64	931.33	784.39
-18 50.5				761.96	607.49	812.76	936.00	862.69	1024.87	658.21	759.63	608.53	758.02	962.67	804.34
-18 51.0				800.30	634.59	853.46	972.69	902.04	1072.63	685.47	790.63	634.29	783.90	996.09	831.25
-18 51.5				840.95	663.67	897.23	1012.52	943.55		714.69	807.41	652.05	811.84	1017.62	856.97
-18 52.0				884.17	693.81	946.08	1052.08	965.65		745.91	840.48	679.80	839.97	1050.77	885.99
-18 52.5				931.96	726.17	995.06		1011.68		769.97	875.02	709.56	869.07		916.48
-18 53.0				981.32	761.06	1047.16		1061.91		803.61	912.06	741.95	900.71		948.17
-18 53.5				1033.18	797.26					838.45	950.31	776.24	931.71		980.10
-18 54.0					835.08					876.70	990.90	812.11	948.85		1012.46
-18 54.5					877.22					915.56	1019.17	835.57	981.35		1034.70
-18 55.0					921.59					957.64	1065.38	875.48	1011.62		
-18 55.5					970.32					1003.29		913.39	1046.78		
-18 56.0					1024.46					1050.20		958.00			
-18 56.5					1080.70							1005.40			
-18 57.0												1057.43			
-18 57.5															
-18 58.0															

Table A2. cont'd.

TMP	TIME	Stress build-up (kPa) at indicate water addition levels (% w/w)														
°C	sec	0	0	0	12	12	12	9	9	9	6	6	6	3	3	3
-11	0.5															
-11	1.0															
-11	1.5								8.85				4.26		11.00	
-11	2.0	8.06	6.27	6.87	12.57	7.82			19.66	9.15	8.96	14.82	10.21	11.43	13.77	11.24
-11	2.5	15.07	17.24	13.03	18.03	14.91	8.99	17.11	22.16	14.15	15.12	21.31	14.69	18.19	16.97	15.29
-11	3.0	16.35	26.28	17.65	21.26	19.22	14.88	20.96	24.52	17.32	19.14	24.38	17.78	20.72	19.33	18.46
-11	3.5	21.99	20.64	20.53	23.59	22.35	17.97	22.94	27.26	19.71	21.64	26.93	21.10	23.35	21.50	20.42
-11	4.0	24.95	31.14	21.12	25.63	24.00	19.63	25.03	29.68	21.83	24.14	29.54	23.05	26.45	23.78	22.16
-11	4.5	22.62	30.79	23.70	27.59	26.28	21.50	27.42	32.15	23.87	26.72	32.01	24.95	29.79	26.17	23.98
-11	5.0	25.36	32.99	27.07	29.54	28.37	23.46	29.13	34.86	25.98	29.13	34.75	26.91	33.18	31.47	26.04
-11	5.5	23.84	43.09	31.22	31.63	30.55	24.95	32.85	37.85	28.16	31.66	37.58	28.92	36.38	33.80	28.43
-11	6.0	33.13	48.79	35.54	32.80	32.69	26.64	35.95	41.05	29.03	34.43	40.56	31.03	39.61	36.79	30.95
-11	6.5	39.10	54.28	34.10	35.08	34.78	28.35	38.99	44.39	31.28	37.28	43.58	33.29	41.27	39.70	33.51
-11	7.0	43.88	59.54	39.48	39.94	37.20	30.22	41.87	47.73	33.67	40.18	46.62	35.65	44.56	42.66	34.24
-11	7.5	48.57	64.97	39.89	42.22	39.61	30.76	44.85	51.07	36.11	43.28	49.80	38.15	48.00	45.78	36.82
-11	8.0	53.49	68.48	46.08	44.77	40.97	32.80	46.84	54.58	38.66	44.04	52.95	40.86	51.53	48.87	39.53
-11	8.5	58.59	73.99	38.28	47.41	43.93	34.94	50.01	58.05	41.35	47.19	56.12	43.55	55.12	52.08	42.25
-11	9.0	63.70	79.04	49.69	50.18	46.57	37.25	53.24	61.58	44.04	50.45	59.52	46.38	58.89	55.50	45.02
-11	9.5	68.97	84.77	51.45	52.95	49.28	39.61	56.64	65.30	46.86	53.73	62.83	49.31	62.69	58.92	47.87
-11	10.0	74.53	90.01	57.62	55.80	52.00	41.98	59.95	68.99	49.85	57.07	66.28	52.21	66.58	62.39	49.77
-11	10.5	80.26	95.93	62.04	58.76	54.85	43.58	63.45	72.85	52.81	60.63	67.28	55.20	70.70	66.17	52.78
-11	11.0	85.91	102.09	67.04	61.69	57.70	46.10	65.73	76.87	55.88	64.19	70.81	58.32	74.80	69.94	55.82
-11	11.5	91.99	108.63	72.06	64.73	60.66	48.41	69.43	80.91	59.14	67.85	74.50	61.50	79.12	73.85	59.11
-11	12.0	95.82	115.15	74.78	67.91	62.56	51.05	72.74	85.12	62.39	71.68	78.33	64.76	83.74	78.06	62.42
-11	12.5	102.20	121.94	79.91	71.03	65.60	53.76	76.57	89.60	65.82	75.62	82.24	68.21	88.41	82.24	65.87
-11	13.0	108.88	126.42	85.39	74.37	68.80	56.61	80.56	94.14	69.32	79.61	86.29	71.63	93.24	86.67	69.54
-11	13.5	115.59	133.48	91.01	77.82	72.06	59.46	84.82	98.81	69.78	83.90	88.98	75.21	98.40	88.87	73.20
-11	14.0	122.64	140.70	96.77	81.35	75.45	62.45	89.06	103.80	72.66	84.93	93.24	79.04	103.64	93.48	77.00
-11	14.5	129.89	148.63	102.66	84.55	78.88	65.54	93.48	108.91	78.06	89.33	97.67	82.81	109.10	98.37	81.18
-11	15.0	137.47	156.31	108.93	88.27	81.13	68.69	96.50	114.20	83.82	93.92	102.36	86.64	114.91	103.50	85.31
-11	15.5	144.99	164.49	115.23	92.04	84.74	71.90	101.28	119.79	88.41	98.56	107.11	90.77	120.83	108.63	89.66
-11	16.0	153.19	169.81	121.75	96.12	88.49	75.40	105.40	125.52	92.99	103.45	112.03	94.95	126.93	114.23	90.93
-11	16.5	161.28	178.20	128.70	100.16	92.48	76.70	110.40	131.55	97.45	108.53	117.32	99.19	133.48	119.82	95.49
-11	17.0	169.45	186.97	131.28	104.37	96.44	80.23	115.59	137.90	102.04	113.77	122.59	103.80	140.10	125.71	100.22
-11	17.5	178.58	193.76	138.20	107.22	100.62	83.87	121.15	144.39	106.82	119.11	125.47	106.57	147.03	131.93	105.35

-11	18.0	180.53	205.08	145.53	111.65	105.02	87.75	126.69	151.05	111.68	121.97	131.12	111.35	154.30	138.34	110.51
-11	18.5	189.63	214.63	153.41	116.26	109.53	91.72	132.58	158.24	116.75	127.59	136.98	116.32	161.85	140.75	115.91
-11	19.0	197.75	224.74	161.17	121.18	111.97	95.76	136.46	165.54	122.10	132.83	143.25	121.45	169.54	147.52	119.50
-11	19.5	207.39	234.94	169.21	126.17	116.64	98.51	142.79	173.17	127.64	138.91	149.52	126.72	177.90	154.68	125.31
-11	20.0	216.26	240.46	177.95	131.28	121.48	102.85	149.12	181.29	133.34	145.43	156.15	132.31	179.85	162.12	131.25
-11	20.5	226.28	250.88	186.61	134.73	126.66	107.39	155.77	189.49	139.40	151.94	163.10	138.01	188.24	169.75	137.74
-11	21.0	237.14	261.88	195.30	140.18	131.90	112.19	160.98	197.80	145.51	158.78	170.27	143.85	195.90	178.03	144.20
-11	21.5	247.87	273.55	204.91	145.81	137.31	117.02	168.07	207.03	151.94	166.09	174.04	146.97	205.13	186.32	151.05
-11	22.0	259.11	285.09	214.42	151.89	140.97	122.07	175.40	216.35	159.03	173.45	181.59	153.19	214.91	194.76	158.29
-11	22.5	270.92	296.96	224.46	158.00	146.78	125.44	183.33	225.98	165.95	181.16	189.44	159.54	224.90	199.40	165.65
-11	23.0	282.79	305.00	227.21	164.40	152.84	130.87	190.66	236.52	173.26	187.48	197.80	166.44	235.22	208.61	169.62
-11	23.5	294.98	317.73	237.52	171.16	159.33	136.44	199.38	239.04	181.05	197.26	205.73	173.53	246.21	218.41	177.52
-11	24.0	307.74	330.38	248.28	178.09	165.95	142.36	208.23	249.72	189.03	205.81	214.88	180.99	257.37	228.43	185.72
-11	24.5	320.80	344.45	259.52	185.28	172.82	148.41	217.13	259.52	197.20	214.93	220.85	188.68	268.91	238.64	193.86
-11	25.0	325.85	357.92	270.95	192.99	180.21	154.74	221.94	271.08	206.06	217.19	230.19	196.66	281.32	249.82	203.10
-11	25.5	339.34	372.36	282.68	195.98	186.75	158.97	231.50	281.94	215.10	226.74	240.02	205.02	293.73	260.93	212.38
-11	26.0	352.08	381.70	295.36	204.15	195.14	165.79	241.38	294.49	224.57	236.98	250.39	213.63	298.59	272.44	222.37
-11	26.5	366.36	396.99	307.90	210.75	203.48	172.74	251.86	307.90	234.75	247.38	260.96	222.67	311.81	284.90	232.37
-11	27.0	379.45	410.26	321.04	219.47	206.65	180.32	262.50	321.59	244.99	258.11	272.09	232.28	324.11	297.45	243.01
-11	27.5	394.95	426.07	334.84	228.54	215.29	187.62	273.55	335.57	255.80	269.70	283.95	241.95	338.39	310.56	254.22
-11	28.0	411.11	442.25	340.08	237.99	224.25	195.71	285.56	350.80	267.17	281.35	295.82	252.21	351.59	324.44	265.52
-11	28.5	427.23	459.46	354.55	247.68	233.75	201.11	297.48	366.30	278.88	293.32	308.17	263.10	366.66	338.72	277.44
-11	29.0	444.15	476.51	367.28	257.91	243.52	209.72	309.96	382.30	291.07	299.65	321.50	274.07	380.99	353.30	290.12
-11	29.5	461.80	494.38	382.41	264.65	253.73	218.57	323.32	399.24	304.24	312.41	326.50	285.50	397.53	369.07	302.99
-11	30.0	479.96	513.09	397.61	275.51	260.63	228.18	336.79	416.56	317.38	326.12	340.40	297.75	412.79	384.74	316.48
-11	30.5	498.34	531.96	414.47	286.70	271.33	237.85	350.83	422.94	331.25	339.75	352.57	310.35	430.84	401.25	330.95
-11	31.0	517.87	542.11	426.72	298.97	282.84	248.00	354.79	441.19	346.08	353.92	367.34	323.35	447.22	418.82	345.37
-11	31.5	537.12	562.12	443.80	311.13	295.03	258.89	369.67	458.11	361.09	369.07	382.46	337.33	466.44	436.57	360.60
-11	32.0	557.32	582.46	461.44	324.08	307.28	269.97	384.82	477.65	376.81	384.39	398.62	351.26	483.82	455.12	376.65
-11	32.5	578.74	604.29	479.88	332.72	320.17	275.94	401.30	495.71	393.43	400.08	415.10	365.87	504.26	474.67	392.97
-11	33.0	599.78	625.66	498.72	346.40	328.78	287.73	417.70	516.83	410.43	417.02	432.09	381.46	525.69	494.49	409.94
-11	33.5	621.88	648.06	517.97	360.63	342.60	299.95	435.03	539.80	428.16	433.94	443.61	397.12	547.54	514.99	428.16
-11	34.0	644.77	663.16	538.34	375.89	355.39	313.20	446.67	562.61	447.19	440.35	461.55	413.82	564.35	536.79	446.43
-11	34.5	668.45	685.94	559.25	391.56	370.35	323.38	465.06	580.53	466.25	458.32	478.41	431.25	587.05	558.84	456.29
-11	35.0	692.10	707.82	570.11	407.63	386.02	337.17	484.14	605.49	486.21	474.72	497.69	449.09	608.15	581.54	475.62
-11	35.5	717.70	732.18	591.69	418.74	402.74	351.72	504.40	628.75	507.44	493.78	517.95	467.61	633.02	605.70	495.98
-11	36.0	742.85	754.66	614.07	435.98	415.69	367.26	525.63	655.74	528.84	511.49	539.23	487.65	658.76	629.76	517.38
-11	36.5	762.29	781.24	637.99	452.16	433.15	379.04	546.70	681.35	551.45	531.58	560.87	507.52	684.71	654.93	538.88
-11	37.0	789.19	807.60	661.47	470.62	451.70	395.47	560.47	711.59	575.29	550.26	583.14	528.48	711.57	681.54	561.42
-11	37.5	816.81	835.68	686.21	488.19	471.33	412.57	582.95	740.27	599.81	571.79	606.98	547.57	739.72	708.77	576.51
-11	38.0	844.91	856.86	702.61	508.31	491.75	430.68	606.44	774.18	618.87	595.00	631.12	570.02	768.40	736.63	600.33
-11	38.5	866.66	885.20	728.75	529.22	512.68	449.34	631.14	811.57	645.32	618.33	656.10	590.85	797.50	766.25	625.01

-11	39.0	895.57	914.15	755.36	551.75	526.20	468.78	656.07	850.64	670.32	642.49	682.62	614.83	828.78	795.57	651.45
-11	39.5	927.10	944.72	784.12	575.10	548.60	481.94	681.94	881.54	700.30	667.85	708.88	637.04	859.41	825.96	671.63
-11	40.0	957.89	974.94	812.41	600.35	572.63	502.42	699.19	923.65	733.67	693.27	736.11	662.78	891.75	858.35	698.64
-11	40.5	990.47	1006.25	841.98	618.08	599.10	524.14	726.53	962.56	768.86	719.82	743.63	690.50	925.44	890.23	726.85
-11	41.0	1024.79	1026.15	861.93	646.86	626.28	547.38	754.66	1007.71	797.67	747.98	772.36	718.27	959.98	923.70	756.64
-11	41.5	1058.11	1058.84	892.97	678.06	656.23	571.11	784.74	1049.63	838.34	776.41	801.71	740.05	995.38	958.46	786.37
-11	42.0			926.28	712.52	677.00	596.06	807.71		882.98	787.10	832.96	770.24	1031.74	994.16	817.81
-11	42.5			960.25	747.41	710.81	613.03	838.88		928.67	817.02	864.43	802.12	1068.59	1030.33	838.28
-11	43.0			986.07	783.38	741.87	640.19	872.14		975.84	848.87	896.61	835.71		1069.27	871.19
-11	43.5			1021.80	807.41	777.55	665.98	908.47		1026.77	880.53	931.74	871.00			901.68
-11	44.0			1057.73	845.37	813.79	696.82	937.04		1076.92	913.58	967.47	908.61			937.04
-11	44.5				880.61	853.08	727.61	976.51			949.15	986.70	945.62			970.08
-11	45.0				921.67	893.86	762.75	1018.33			985.42	1024.00	985.85			1006.65
-11	45.5				964.92	935.90	795.17	1063.97			1022.92	1063.75	1028.94			1040.89
-11	46.0				1011.49	963.05	832.99				1062.18		1072.20			
-11	46.5				1047.63	1008.04	872.90									
-11	47.0					1055.31	915.88									
-11	47.5						949.63									
-11	48.0						996.80									
-11	48.5						1045.26									
-11	49.0															

TMP °C	TIME sec	Stress build-up (kPa) at indicate water addition levels (% w/w) 0	0	0	9	9	9	6	6	6	3	3	3
-8	0.5		2.77	2.42		1.25		1.85			1.19		
-8	1.0	2.61	7.30	6.87	2.23	2.66	1.95	3.20	1.68	1.14	3.12	2.12	1.93
-8	1.5	6.63	11.68	8.04	4.21	3.53	3.77	4.21	2.72	2.12	4.64	3.29	2.99
-8	2.0	11.27	14.61	9.23	5.67	4.32	5.10	5.16	3.42	3.01	5.02	4.18	3.77
-8	2.5	8.77	16.83	9.58	6.92	5.05	5.81	6.03	4.13	3.75	6.63	4.89	4.48
-8	3.0	13.20	12.76	10.40	8.01	5.73	6.79	6.90	4.81	4.53	6.60	5.54	5.19
-8	3.5	14.74	18.35	11.97	7.90	6.46	7.71	7.77	5.46	5.27	5.92	6.14	5.81
-8	4.0	18.33	14.61	13.28	9.96	7.11	8.61	7.96	6.16	5.89	4.56	6.71	6.41
-8	4.5	15.59	18.73	12.49	11.00	7.82	9.48	8.80	6.84	6.16	7.36	7.25	7.03
-8	5.0	22.05	20.04	15.01	11.65	8.47	10.40	9.64	7.55	6.79	8.58	7.77	7.60
-8	5.5	24.19	22.13	13.63	12.60	9.18	11.27	10.45	8.20	7.39	9.12	8.25	8.15
-8	6.0	28.29	26.17	14.04	13.55	9.72	12.16	11.19	8.91	8.06	9.75	8.80	8.74
-8	6.5	31.50	29.41	16.94	14.50	10.43	12.41	12.00	9.58	8.80	11.30	9.42	9.34
-8	7.0	34.73	32.31	18.87	15.50	11.16	13.39	12.79	10.26	9.53	12.14	10.07	9.88
-8	7.5	37.82	33.91	20.85	16.59	11.92	14.39	13.63	10.97	10.26	12.35	10.78	10.48

-8	8.0	27.88	37.63	17.54	17.84	12.68	15.45	14.06	11.70	11.00	13.20	11.57	11.08
-8	8.5	41.62	40.78	21.50	19.11	13.47	16.18	14.99	12.49	11.73	14.12	12.38	11.65
-8	9.0	45.75	44.04	26.20	19.79	14.25	17.24	15.97	13.36	12.54	14.44	13.22	12.00
-8	9.5	49.36	47.43	28.35	21.10	15.12	18.35	16.97	14.17	13.36	14.80	14.15	12.71
-8	10.0	52.95	50.77	26.17	22.29	16.02	19.55	18.03	15.07	14.23	16.07	15.04	13.39
-8	10.5	56.39	52.05	31.74	23.68	16.97	20.74	19.14	16.02	15.10	16.94	15.97	14.20
-8	11.0	60.09	55.58	34.62	25.09	17.89	22.02	20.28	16.62	16.05	17.78	16.94	15.07
-8	11.5	63.83	59.25	37.25	26.61	18.92	23.30	21.45	17.65	16.92	18.65	17.95	15.91
-8	12.0	67.53	62.83	39.97	28.13	20.01	24.60	22.73	18.71	17.95	19.60	18.90	16.73
-8	12.5	71.33	66.47	41.84	29.68	21.07	25.28	23.98	19.82	18.98	20.47	19.96	17.62
-8	13.0	75.35	70.40	44.69	30.68	22.24	26.64	25.22	20.91	20.07	21.42	20.99	18.52
-8	13.5	79.31	72.74	47.57	32.31	23.38	28.05	26.61	22.02	21.15	22.43	22.02	19.41
-8	14.0	83.44	76.62	50.72	33.94	24.60	29.49	26.93	23.24	22.35	23.46	23.11	19.90
-8	14.5	87.73	80.78	53.73	35.68	25.85	30.98	28.29	24.46	23.54	23.81	24.22	20.83
-8	15.0	91.94	84.85	56.88	37.39	27.12	32.53	29.73	25.03	24.79	24.90	25.31	21.78
-8	15.5	96.31	89.09	59.00	39.21	28.46	34.10	31.28	26.34	26.09	26.01	26.47	22.83
-8	16.0	100.90	93.43	62.29	41.08	29.84	35.73	32.77	27.69	27.40	27.10	27.67	23.92
-8	16.5	105.46	97.94	65.65	42.98	31.20	37.42	34.35	29.08	28.75	28.32	28.89	24.98
-8	17.0	109.99	102.34	69.16	43.99	32.66	39.15	35.98	30.49	30.17	29.51	30.17	26.04
-8	17.5	115.02	107.11	72.66	45.94	33.40	39.83	37.63	31.98	31.58	30.74	31.44	27.12
-8	18.0	119.85	111.87	76.30	47.95	34.94	41.65	39.40	33.51	33.10	31.98	32.77	28.29
-8	18.5	124.93	116.78	78.71	50.15	36.30	43.61	41.13	35.08	34.67	33.29	34.16	29.46
-8	19.0	130.14	121.78	82.62	52.35	37.90	45.53	42.95	35.89	35.05	34.59	35.51	30.68
-8	19.5	135.32	126.80	86.48	54.63	39.64	47.57	44.91	37.61	36.65	35.92	36.93	31.93
-8	20.0	140.70	131.98	90.55	56.18	41.30	49.74	45.40	39.40	38.34	37.39	38.42	33.21
-8	20.5	146.27	137.36	94.60	58.62	43.04	51.91	47.33	41.19	40.08	37.74	39.94	34.48
-8	21.0	147.71	142.95	98.81	61.15	44.91	54.14	49.14	43.04	41.90	39.15	41.46	35.89
-8	21.5	153.08	148.28	101.55	64.00	46.78	55.34	51.15	44.96	43.80	40.46	43.14	37.28
-8	22.0	159.16	154.28	105.95	66.74	48.76	57.72	53.43	46.95	45.64	41.98	44.85	38.66
-8	22.5	165.14	160.01	109.86	69.56	50.83	60.25	55.72	49.04	47.62	43.55	46.54	39.97
-8	23.0	171.33	166.20	114.44	71.41	52.92	62.83	58.05	50.12	49.74	45.21	48.14	41.43
-8	23.5	177.76	172.66	119.03	74.40	55.09	65.49	60.66	52.29	51.89	46.92	49.96	43.06
-8	24.0	184.09	178.98	123.84	77.49	57.43	68.31	63.10	54.63	54.06	48.68	51.89	44.69
-8	24.5	190.74	185.69	128.70	80.78	59.82	71.19	65.76	56.91	56.48	50.50	53.79	46.46
-8	25.0	197.64	189.09	133.86	84.09	62.26	74.15	68.31	59.30	58.84	52.29	55.80	48.19
-8	25.5	204.72	195.85	139.26	87.56	64.87	75.73	71.22	61.88	61.31	53.16	57.86	49.96
-8	26.0	207.33	202.93	144.56	91.26	67.45	78.88	74.18	64.43	64.00	55.09	59.95	51.45
-8	26.5	214.39	210.26	147.49	95.17	70.19	82.27	77.22	67.26	66.63	57.07	62.15	52.51
-8	27.0	222.10	217.70	153.08	99.16	73.15	85.66	80.40	70.21	69.48	59.06	63.32	54.58
-8	27.5	229.57	225.63	158.13	103.20	76.13	89.25	83.74	73.20	72.47	61.17	65.52	56.80
-8	28.0	237.47	233.13	164.21	104.72	79.23	93.05	87.18	76.35	75.56	63.35	67.88	59.00
-8	28.5	245.70	241.52	170.24	109.07	82.54	96.93	90.80	79.61	78.66	65.57	70.24	61.06

-8	29.0	253.79	250.10	176.87	113.47	85.85	100.95	94.49	82.98	82.11	67.88	72.74	63.32
-8	29.5	262.53	258.70	183.00	118.27	89.36	103.07	98.48	86.53	85.62	70.32	75.35	65.57
-8	30.0	266.88	267.55	189.60	123.08	93.08	107.36	102.61	90.25	89.25	72.74	77.93	67.91
-8	30.5	275.73	276.73	194.00	128.05	96.90	111.92	106.84	94.03	91.12	75.26	80.64	70.46
-8	31.0	285.12	286.21	200.65	131.39	100.87	116.48	111.32	98.02	95.03	77.95	83.49	73.04
-8	31.5	294.71	295.87	207.03	136.79	105.10	121.34	115.86	102.25	98.64	80.56	86.40	75.59
-8	32.0	301.93	306.19	214.44	142.60	109.48	126.50	120.74	106.60	102.82	83.33	89.44	78.58
-8	32.5	311.78	316.37	221.02	148.47	114.04	131.77	123.21	111.11	107.41	86.23	92.67	79.28
-8	33.0	321.04	327.18	228.81	154.41	118.87	137.28	128.32	116.02	112.03	89.22	95.87	82.00
-8	33.5	331.63	338.58	236.60	160.96	123.89	143.20	133.83	121.07	116.94	92.29	99.24	84.88
-8	34.0	342.63	350.12	245.21	167.91	129.08	149.23	139.34	126.28	122.07	95.49	102.74	87.94
-8	34.5	353.79	361.42	253.62	174.91	133.83	155.42	145.18	131.96	127.34	98.75	106.30	91.20
-8	35.0	365.44	373.61	262.75	178.74	139.40	162.23	151.51	137.61	132.83	102.12	109.88	94.49
-8	35.5	377.44	386.15	272.03	186.32	145.34	163.86	157.89	143.61	138.83	105.78	113.77	97.91
-8	36.0	389.85	398.89	281.40	193.38	151.67	170.84	164.65	150.01	144.91	109.34	117.81	101.38
-8	36.5	402.34	412.63	286.21	201.49	158.19	178.31	168.23	151.53	151.24	113.11	121.94	103.31
-8	37.0	415.97	426.04	296.47	210.18	165.08	185.99	175.43	158.13	158.08	117.11	126.31	107.06
-8	37.5	429.16	440.57	305.38	219.41	171.98	193.95	182.13	165.35	159.79	121.18	130.68	111.02
-8	38.0	443.04	455.25	315.31	228.75	179.45	202.47	189.95	172.74	166.85	125.36	135.30	114.88
-8	38.5	457.40	469.97	326.01	238.37	187.40	211.24	198.53	180.48	174.53	129.89	140.24	119.25
-8	39.0	472.25	485.61	337.61	244.94	195.57	220.36	207.09	188.79	182.27	134.46	145.18	123.79
-8	39.5	487.56	501.77	348.55	255.36	204.21	225.22	216.26	197.45	190.42	139.15	150.31	128.37
-8	40.0	503.37	518.03	360.66	266.55	213.41	235.08	226.01	206.73	199.27	144.15	155.80	133.26
-8	40.5	519.55	534.51	373.20	278.50	215.64	245.67	236.11	216.78	208.36	149.06	161.42	138.31
-8	41.0	535.79	549.58	385.58	290.66	225.31	256.45	246.67	227.02	217.97	154.44	167.09	143.61
-8	41.5	551.43	567.45	398.53	303.69	234.13	267.74	258.08	237.66	223.00	160.01	173.07	148.95
-8	42.0	568.88	583.57	411.97	312.27	244.61	279.88	269.70	249.04	233.32	165.60	179.42	154.85
-8	42.5	584.74	602.58	416.86	326.07	255.91	292.21	282.08	260.74	244.53	171.60	185.91	156.18
-8	43.0	603.96	619.44	430.93	340.46	267.58	305.16	295.22	272.90	255.85	177.87	192.97	161.99
-8	43.5	623.54	639.42	445.29	355.99	279.80	312.11	308.88	286.23	267.96	184.31	199.78	167.26
-8	44.0	643.58	658.21	461.01	371.74	292.97	326.04	323.11	299.65	280.94	190.09	207.06	173.91
-8	44.5	664.30	679.50	472.82	388.54	306.38	339.07	338.64	314.28	294.14	198.05	214.61	179.80
-8	45.0	686.40	702.12	488.57	406.60	320.61	354.30	354.17	330.19	308.15	205.21	222.67	186.75
-8	45.5	708.69	724.55	505.40	424.79	335.95	368.50	370.92	344.31	323.16	212.87	230.76	194.16
-8	46.0	731.04	748.17	522.75	444.12	351.67	385.26	389.19	360.98	338.69	221.02	235.11	201.82
-8	46.5	755.58	773.28	536.38	464.95	367.99	403.26	408.09	379.26	355.04	229.24	243.88	209.67
-8	47.0	779.07	798.05	554.85	486.26	385.77	421.97	426.93	397.72	372.79	237.85	253.33	218.22
-8	47.5	804.59	823.38	573.93	508.66	404.15	441.71	447.60	417.30	390.93	247.14	262.91	226.93
-8	48.0	831.04	850.34	594.95	532.91	423.51	463.43	469.05	438.39	410.13	256.53	273.01	236.06
-8	48.5	858.11	878.36	616.10	557.75	444.56	485.50	491.77	459.90	431.01	266.36	283.98	245.86
-8	49.0	885.80	906.03	637.44	584.28	465.95	508.58	516.62	468.34	452.46	276.98	294.76	255.58
-8	49.5	914.88	936.03	651.78	613.47	488.73	533.78	542.28	491.94	475.18	287.70	306.30	265.92

-8	50.0	944.88	942.90	673.69	644.64	510.02	559.87	552.32	514.20	500.03	299.02	318.84	276.84		
-8	50.5	974.91	972.31	697.29	674.86	535.43	588.22	580.42	540.51	526.36	311.02	331.41	288.60		
-8	51.0	1008.17	1004.48	721.80	710.83	559.25	618.44	611.73	565.73	554.39	323.54	344.72	300.90		
-8	51.5	1040.29	1035.14	747.14	749.15	587.43	650.45	644.58	595.98	585.09	336.47	359.14	314.01		
-8	52.0			772.88	791.53	618.06	685.01	680.53	625.33	617.43	350.61	373.47	327.31		
-8	52.5			801.17	835.03	650.04	722.65	720.53	660.49	652.57	365.03	388.84	341.84		
-8	53.0			828.51	881.27	684.20	761.06	762.40	694.95	690.93	380.02	404.91	357.34		
-8	53.5			857.26	931.88	721.69	802.23	806.92	736.44	730.46	396.44	421.88	372.63		
-8	54.0			887.86	983.36	759.68	847.68	855.55	775.92	745.97	412.65	439.34	384.31		
-8	54.5			918.14	1038.31	803.18	894.43	905.68	822.70	789.25	430.19	458.16	401.30		
-8	55.0			950.01		850.10	945.02	959.79	873.45	830.06	448.60	477.38	419.58		
-8	55.5			983.41		898.86	999.87	1019.12	926.77	878.66	467.53	492.43	438.42		
-8	56.0			1017.49		954.17	1056.99	1080.64	982.79	925.12	487.37	513.85	457.94		
-8	56.5			1052.05		1014.58			1044.50	980.86	508.66	536.90	479.53		
-8	57.0					1077.65				1042.74	530.52	560.20	501.25		
-8	57.5										553.33	585.34	524.38		
-8	58.0										578.50	612.49	549.31		
-8	58.5										603.86	640.05	575.73		
-8	59.0										630.93	669.40	585.66		
-8	59.5										659.92	701.87	613.85		
-8	60.0										689.95	735.49	643.63		
-8	60.5										722.59	748.69	675.05		
-8	61.0										757.24	784.55	699.89		
-8	61.5										792.72	823.92	734.46		
-8	62.0										831.28	865.25	772.25		
-8	62.5										872.96	909.37	810.86		
-8	63.0										915.12	956.37	852.30		
-8	63.5										960.03	1005.00	896.85		
-8	64.0										1007.79	1055.55	943.12		
-8	65.0										1056.78		992.64		
													1046.21		

Stress build-up (kPa) at indicate water addition levels (% w/w)

TMP °C	TIME sec	0	0	0	12	12	12	9	9	9	6	6	6	3	3	3
-5	0.5													9.56		
-5	1.0													18.22		
-5	1.5													21.12		
-5	2.0			6.76				3.80	3.12					23.46		
-5	2.5	3.23		14.88	5.48	10.02		11.35	14.09	5.10	8.15	10.67	10.89	25.55	12.82	1.90
-5	3.0	9.29	1.36	17.76	9.45	12.68		15.37	16.24	7.55	19.93	15.75	15.10	27.78	19.09	6.68

-5	3.5	14.17	8.69	17.46	13.22	14.47		17.65	17.97	9.12	23.68	18.87	17.30	30.06	22.67	12.41
-5	4.0	14.99	13.60	21.21	15.45	16.10		18.95	19.55	9.58	25.25	21.50	18.57	32.45	25.17	15.61
-5	4.5	15.48	17.51	22.92	17.62	17.54	8.53	20.50	20.93	10.86	27.53	23.84	20.47	34.75	27.45	17.24
-5	5.0	18.49	18.49	22.56	19.28	19.03	11.27	21.99	22.45	12.03	29.79	26.07	22.21	36.00	29.65	19.36
-5	5.5	17.81	22.18	26.53	20.93	20.34	12.79	23.68	23.89	13.20	32.17	28.40	24.00	38.58	31.88	21.29
-5	6.0	19.36	16.10	25.25	22.62	21.88	14.01	25.55	25.58	14.34	34.59	30.71	25.82	40.92	34.13	23.27
-5	6.5	21.86	24.22	31.17	24.46	23.46	15.42	27.45	27.50	15.45	37.06	31.96	27.56	43.58	36.46	25.17
-5	7.0	23.95	26.74	35.57	26.36	24.36	16.78	29.38	29.51	16.62	39.70	34.48	29.68	46.32	38.88	27.10
-5	7.5	27.45	28.24	38.07	27.91	26.09	17.35	31.31	31.66	17.73	42.25	37.17	31.74	49.09	41.46	28.51
-5	8.0	31.96	32.45	38.45	30.19	27.91	18.76	33.37	33.83	18.92	44.88	40.08	32.85	52.02	44.20	30.63
-5	8.5	32.96	38.99	43.80	32.26	29.87	20.20	35.51	35.27	20.09	47.65	42.98	35.08	55.15	47.05	32.85
-5	9.0	34.97	46.46	48.57	34.21	31.85	21.67	37.61	37.52	20.55	48.71	45.91	37.33	58.10	50.12	35.16
-5	9.5	40.48	47.33	54.11	36.41	33.91	23.16	39.91	39.83	21.83	51.51	49.04	39.78	61.50	53.14	36.84
-5	10.0	34.92	55.96	59.25	38.72	36.08	24.14	42.28	42.22	23.16	54.33	52.08	42.22	64.70	56.31	23.19
-5	10.5	45.26	50.12	59.30	41.05	38.34	26.45	44.53	44.66	24.49	57.34	53.71	44.80	68.18	59.57	35.84
-5	11.0	47.46	56.94	68.15	41.71	39.51	28.89	47.08	47.11	25.82	60.30	56.86	46.51	71.65	62.91	41.24
-5	11.5	52.24	65.98	73.26	44.18	41.65	30.14	49.42	48.74	27.29	63.43	60.14	49.20	75.35	66.28	43.31
-5	12.0	49.04	72.09	79.45	46.70	43.71	31.63	51.89	51.32	28.75	65.52	63.59	51.97	79.12	69.92	46.51
-5	12.5	47.11	78.31	85.47	49.31	46.24	33.37	54.25	53.95	30.27	68.78	67.06	54.87	83.00	73.53	50.29
-5	13.0	64.73	84.58	91.66	52.02	48.47	35.38	56.96	56.80	31.88	72.22	70.62	57.81	87.10	77.33	53.60
-5	13.5	62.61	90.82	98.21	54.85	51.83	35.89	59.95	59.60	33.48	75.81	73.01	60.85	91.34	79.28	56.80
-5	14.0	62.39	97.69	104.78	56.80	53.76	37.93	62.88	62.58	35.22	79.36	76.79	62.83	95.63	83.25	60.14
-5	14.5	63.54	104.32	111.54	59.82	56.31	40.05	65.92	65.73	37.09	83.08	80.70	66.03	100.14	86.89	62.37
-5	15.0	78.60	111.24	118.82	62.97	59.11	42.25	69.07	68.91	38.96	87.02	84.77	69.26	104.72	91.07	65.87
-5	15.5	80.51	118.44	126.01	66.28	61.99	44.53	72.33	70.65	40.92	90.99	88.79	72.79	109.50	95.52	69.45
-5	16.0	88.05	125.58	132.80	69.56	64.87	47.03	75.81	74.10	42.95	93.13	93.08	76.32	114.55	100.11	73.26
-5	16.5	92.34	132.94	140.35	72.96	67.96	49.52	79.45	77.60	45.02	97.31	97.39	79.99	119.66	104.72	77.08
-5	17.0	88.08	134.97	148.22	76.60	71.35	52.21	83.25	81.48	47.14	101.63	101.93	83.90	124.98	109.75	81.10
-5	17.5	100.35	142.57	156.72	80.29	74.67	53.62	87.16	85.28	49.44	106.22	104.29	87.86	130.63	114.72	83.79
-5	18.0	110.81	150.20	165.27	82.24	78.17	56.39	91.28	89.25	51.72	110.89	109.07	89.90	136.44	120.01	88.05
-5	18.5	116.35	158.70	174.02	86.07	81.92	59.46	95.47	91.99	54.14	115.78	113.41	94.05	142.33	122.70	92.48
-5	19.0	126.47	166.87	179.88	90.09	85.72	62.31	99.84	96.25	56.72	118.98	118.44	98.45	148.68	128.27	97.18
-5	19.5	134.70	175.45	188.73	94.76	89.57	65.41	104.53	100.22	59.33	124.11	123.70	103.07	155.12	134.13	101.96
-5	20.0	139.61	181.10	198.29	99.05	90.74	68.86	109.29	104.83	62.04	129.46	129.32	107.82	161.80	140.16	106.92
-5	20.5	149.12	189.90	208.28	103.64	94.73	72.31	114.25	109.67	64.89	135.22	133.53	112.82	168.94	146.40	110.26
-5	21.0	158.46	198.37	218.30	108.20	99.02	75.92	119.52	114.80	67.85	140.89	139.32	116.24	176.08	153.03	115.56
-5	21.5	168.50	208.34	228.75	113.20	103.72	79.80	125.06	120.04	70.97	146.89	145.32	121.59	183.65	159.73	121.12
-5	22.0	178.20	218.03	235.57	115.86	108.47	83.71	130.68	125.47	74.26	153.27	151.67	127.15	191.64	166.66	127.04
-5	22.5	188.19	227.86	246.48	120.99	113.20	87.75	136.74	131.22	75.05	159.63	158.05	133.04	199.76	174.12	132.99
-5	23.0	198.86	238.56	257.64	126.20	116.54	91.99	143.12	137.04	78.39	166.30	164.78	139.04	208.28	181.62	139.26
-5	23.5	209.50	248.98	269.56	131.90	121.69	96.33	149.52	140.24	81.46	173.36	171.98	145.32	217.21	189.38	145.83
-5	24.0	220.55	254.79	281.43	137.63	127.02	100.81	152.92	146.46	85.15	176.08	179.20	152.05	225.96	197.75	152.35

-5	24.5	232.07	265.68	293.57	143.61	132.83	105.59	159.87	153.08	89.03	183.49	186.72	159.11	235.68	199.73	159.41
-5	25.0	243.85	277.19	306.63	147.22	138.77	110.43	167.45	160.14	93.02	190.96	194.60	162.53	246.00	208.28	166.96
-5	25.5	255.55	288.79	319.39	153.68	145.02	115.42	175.07	167.34	97.15	198.94	202.53	169.67	256.34	217.30	169.94
-5	26.0	259.11	297.83	326.36	160.25	148.79	120.83	183.08	174.88	101.60	207.36	210.92	177.03	267.26	226.66	177.65
-5	26.5	271.36	310.05	339.91	167.39	154.93	126.26	191.39	182.76	106.16	215.88	219.93	185.07	278.47	236.36	185.83
-5	27.0	283.98	322.43	353.87	174.69	161.77	131.85	200.08	190.90	110.92	221.37	229.11	193.16	290.20	247.00	194.41
-5	27.5	297.39	335.62	368.59	182.32	168.88	138.09	209.15	199.43	115.99	230.30	238.53	201.19	302.20	257.43	203.23
-5	28.0	310.62	345.59	383.52	187.46	176.03	144.31	218.84	208.63	121.26	239.70	248.68	210.32	315.29	268.26	212.33
-5	28.5	324.41	358.87	398.78	195.55	183.57	150.96	228.86	218.00	126.85	249.85	258.95	219.47	328.35	279.85	218.46
-5	29.0	338.53	372.77	415.21	203.20	188.73	158.27	239.13	227.83	132.64	259.95	268.67	229.00	341.98	291.56	228.35
-5	29.5	353.30	387.48	431.22	211.89	196.85	164.54	250.23	238.31	134.08	270.54	279.58	239.18	356.67	303.83	238.58
-5	30.0	368.10	401.90	448.14	221.02	205.40	171.63	261.53	249.04	140.16	277.65	291.15	243.12	371.30	316.64	249.69
-5	30.5	384.20	417.00	465.68	230.90	214.55	179.34	273.34	260.11	145.86	288.81	303.20	253.52	386.59	330.22	260.66
-5	31.0	400.00	432.75	483.44	240.89	223.81	181.18	285.91	272.09	152.54	300.52	312.60	264.57	402.80	343.96	272.31
-5	31.5	416.13	448.76	501.66	251.32	233.64	189.17	298.75	284.17	158.59	312.92	325.52	276.27	419.12	358.81	284.80
-5	32.0	433.29	457.18	506.60	262.37	243.96	197.42	312.19	295.71	166.11	325.85	338.72	288.05	436.28	373.45	297.29
-5	32.5	449.96	473.83	525.71	273.72	254.58	206.52	326.61	308.72	174.07	338.94	352.76	300.30	454.71	389.06	310.10
-5	33.0	467.88	491.04	545.13	279.69	260.17	215.86	341.33	322.48	181.92	347.27	367.04	313.55	473.34	403.34	324.22
-5	33.5	486.29	509.23	565.82	291.56	271.33	225.60	356.58	337.33	190.20	361.28	381.94	326.77	492.37	420.20	338.45
-5	34.0	505.05	522.81	586.34	303.96	283.06	235.54	372.98	348.76	198.83	375.81	392.04	340.67	512.54	435.38	353.35
-5	34.5	521.86	540.95	607.68	317.32	295.63	245.89	389.63	364.32	208.06	391.34	407.82	355.50	533.21	453.22	357.62
-5	35.0	541.57	560.28	621.99	330.76	305.13	251.40	406.98	380.51	217.57	403.15	422.64	370.40	554.93	469.75	373.12
-5	35.5	561.39	580.23	643.80	344.69	318.25	262.59	425.52	398.10	227.67	419.20	439.64	386.10	577.76	488.95	389.47
-5	36.0	583.17	600.84	667.04	354.11	330.25	274.61	444.56	411.59	238.18	436.14	457.45	402.88	600.76	506.63	406.98
-5	36.5	604.26	621.37	691.20	369.13	344.28	286.64	452.08	430.46	249.17	454.14	476.73	419.77	624.68	527.37	424.36
-5	37.0	626.77	643.42	709.69	383.17	359.00	299.59	472.66	450.18	261.04	472.52	496.20	437.47	646.48	549.53	442.52
-5	37.5	649.99	665.19	735.00	399.65	374.67	312.98	494.87	471.65	263.83	491.80	516.26	456.39	672.12	571.74	454.58
-5	38.0	673.45	676.98	760.55	416.59	390.90	326.80	517.89	493.73	275.89	504.51	537.52	475.43	699.54	589.06	474.19
-5	38.5	685.77	699.59	787.95	434.86	406.65	341.35	542.47	517.95	288.95	524.60	558.89	493.38	727.04	612.82	494.54
-5	39.0	710.51	723.51	815.10	448.82	417.78	356.75	569.07	534.27	302.31	543.20	570.43	514.01	755.72	638.07	516.73
-5	39.5	735.60	748.00	843.85	467.74	435.19	372.74	596.77	560.14	316.45	564.76	592.62	533.23	786.32	663.67	533.02
-5	40.0	762.21	766.71	874.04	487.32	451.64	389.36	625.74	587.08	331.44	586.86	613.41	555.34	817.51	690.01	555.61
-5	40.5	788.43	792.64	904.26	509.01	470.24	407.20	656.88	615.75	346.95	610.67	637.71	578.69	850.48	718.06	578.88
-5	41.0	814.50	818.36	935.19	531.14	488.38	425.31	688.73	644.56	363.70	628.84	663.16	603.72	886.23	746.48	603.83
-5	41.5	832.77	846.24	967.42	554.77	509.29	444.61	700.98	675.08	381.48	653.57	690.47	628.94	923.11	776.22	629.13
-5	42.0	860.44	873.93	999.73	580.42	531.55	465.22	734.70	695.66	399.65	679.45	717.89	655.28	962.31	808.01	656.12
-5	42.5	889.98	902.12	1032.01	607.11	555.44	486.04	766.31	728.35	418.25	707.28	746.89	673.12	1004.45	841.03	673.99
-5	43.0	920.15	932.15		636.33	579.88	508.01	803.18	762.94	438.28	735.41	777.90	702.12	1047.03	876.84	702.99
-5	43.5	951.05	961.23		667.50	605.65	532.04	843.06	800.19	459.19	765.00	809.69	732.85		914.69	733.70
-5	44.0	982.32	977.11		698.91	623.27	556.69	883.85	838.31	481.92	785.15	826.42	767.26		953.25	766.25
-5	44.5	1003.64	1007.30		731.61	652.46	583.11	926.85	878.50	507.03	817.32	861.61	794.43		993.81	799.21
-5	45.0	1037.61	1035.43		766.50	682.98	612.16	972.71	906.06	533.56	847.76	895.66	833.26		1037.01	834.40

-5 45.5	801.93	716.35	642.06	1020.45	949.93	559.92	882.81	935.92	875.16	857.70
-5 46.0	839.18	750.31	673.93	1070.32	995.82	584.23	919.82	973.64	919.09	895.66
-5 46.5	879.61	786.40	707.06		1045.86	613.03	960.03	1018.71	963.10	930.03
-5 47.0	920.74	810.37	741.03			644.53	1001.39	1065.93	1008.58	973.12
-5 47.5	963.43	849.34	776.41			676.68	1046.29		1057.32	1020.17
-5 48.0	1009.64	883.06	814.47			711.24				1070.27
-5 48.5	1047.46	925.03	854.03			747.95				
-5 49.0		967.53	895.28			786.29				
-5 49.5		1014.53	939.94			826.64				
-5 50.0		1062.59	985.50			870.32				
-5 50.5			1033.89			915.02				
-5 51.0						962.67				
-5 51.5						1014.36				
-5 52.0						1069.56				
-5 52.5										
-5 53.0										

APPENDIX A3

One way of assessing the total work that would be required to compact a 1 m^3 volume of snow from its initial density to 0.8 Mg/m^3 is given below. The parameters that would be considered are: initial density of snow and water mixture; unit work per density change per initial mass of snow and water mixture; density change from initial density to 0.8 Mg/m^3. The total work can then be determined as:

$$(UWork/\Delta\rho/kg) \times \Delta\rho \times (initial\ density \times volume)$$

Values for each snow temperature and water addition level are given in Table A3.

Table A3. Total work (MJ) to compact a 1 m^3 volume of snow from its initial density to 0.8 Mg/m^3.

Water Addition % (w/w)	Snow Temperature °C			
	-18	-11	-8	-5
0	246.3	230.3	245.0	222.0
3	209.3	147.2	126.5	110.7
6	130.4	123.6	103.5	118.9
9	145.2	113.5	107.8	102.4
12	114.6	112.0		107.1